Non-hydro renewable energy in Central Asia

Ovezmyradov, Berdymyrat; Kepbanov, Yolbars

2021

Non-hydro renewable energy in Central Asia

Berdymyrat Ovezmyradov
Sociology of Law Department, Lund University, Lund, Sweden

Yolbars Kepbanov
Tebigy Kuwwat Public Association, Ashgabat, Turkmenistan

Abstract

The cost of renewable energy from wind and solar in 2019 plunged to the low levels that few policy-makers anticipated only several years ago. Such technological developments have broad implications for all Central Asian economies. The share of wind and solar energy in the region remained negligible for a long time due to the abundant supply of cheap energy from fossil or hydro resources. Central Asian countries to a different extent remain dependent on consumption, exports, or transit of fossil fuel. While there was obvious progress in renewables elsewhere in the post-Soviet area, Central Asia until recently has not shown adequate levels of interest in developing wind and solar power. Such an approach could lead to a loss of opportunities in reducing electricity costs and addressing sustainability issues. Governments in the region can seize the opportunities for introducing a more sustainable energy mix during the major modernization and replacement of power generating capacity expected in the coming years. Foreign investors and specialists in installing renewables capacity can benefit from the planned expansions in the wind and solar facilities in Central Asia.

Keywords

Central Asia, renewables, sustainability, solar power, wind power.

Introduction

The past decade in the period from 2000 to 2020 brought spectacular technological developments in renewable energy on the global scale that few policy-makers expected: the cost of wind and solar power sharply decreased to the levels comparable to the cheapest fossil (coal, oil, and gas), while the cost of mature renewables such as hydro, biomass, and geothermal did not change much. The fact that the share of renewables will increase to the detriment of fossils is a boon for the environment and quality of economic development on a global scale. At the same time, gas and oil exports cannot be relied on anymore as steady drivers for future growth in the economies of many countries in view of the green transition.

Central Asian countries that rely on hydrocarbon (Kazakhstan, Uzbekistan, and Turkmenistan) and hydropower (Tajikistan and Kyrgyz Republic) resources have long realized threats presented by changes in commodity markets. They should also be aware of opportunities coming from renewables in the near future after the global demand slows as a result of the COVID-19 pandemic. If existing policies continue, the negative economic impact could be two-fold: decreasing the value of exports and transit coupled with increasing electricity cost for local consumers due to excessive reliance on fossil and hydropower in the national energy mix. The region was still far behind many parts of the world in terms of preparedness for the ongoing green energy revolution. The main focus of local policy-makers has always been on using cheap and abundant fossil and hydro energy with decades of experience in using mature technology. Improved air quality, lower emissions, resilience, and security of electricity supply, and overall better ecology as extra benefits of renewables were probably never prioritized. The timing seems right to substantially enhance the share of non-hydro renewables. Central Asia thus could turn possible threats posed by renewables to dependence on fossil and hydro resources into opportunities for economic and environmental development after the period of uncertainties brought by the pandemic outbreak.

This report aims at addressing the following questions: (i) What is the potential of the Central Asian area for the generation of non-hydro renewable electricity? (ii) What are the achievements of Central Asian states in terms of renewable energy capacity and policies? (iii) How can governments of Central Asia benefit from foreign investments in renewables? (iv) Which threats are presented by non-hydro renewables to Central Asian economies that are dependent on fossil and hydropower resources? These questions are relevant in view of the underdeveloped sector of renewables in respective countries that requires foreign expertise

and funds to fully benefit from the rapidly growing technologies. Extant literature on the recent status of renewables includes relatively little information on Central Asia as a distinct region. Results presented in subsequent sections are mostly based on the analysis of data from relevant industry reports. Comparative analysis of Central Asian countries in this report is limited to the implications of renewables for electricity and fossil exports. Though the share of renewables in alternative transportation and heating/cooling sectors is increasing globally, the research scope of further discussion concentrating on electricity generation and consumption is justified in the case of Central Asia, a region where electric vehicles, solar thermal, and similar energy applications are not likely to play any significant role in the near future.

In the subsequent sections, the following topics are discussed: the general state of renewable energy as of 2020, Central Asian potential for renewables, investment opportunities and threats, corresponding legislation, implications, and summary.

Current state of renewable technology

There is plenty of theoretical and empirical literature available on the subject of renewables covering all their aspects from technology to environment and socio-economic impact. This report is mostly based on hard data provided by two influential organizations in assessments in the field of the world energy market and renewables: International Renewable Energy Agency (IRENA) and REN21. The experience of countries that are at more advanced stages of non-hydro renewable deployment is valuable for Central Asia, as there is currently limited information on specific projects in the region due to the low share of wind and solar. A brief introduction to the state of renewable technology is worth presenting at the beginning before proceeding to economic aspects. Currently, underdeveloped forms of renewables such as ocean and marine (technologies that include wave and tidal but exclude off-shore wind) are not considered in this report, although they have the potential to become significant in the distant future.

Probably everyone knows that common renewables include mature technology such as hydropower, bioenergy, geothermal, on the one side, and rapidly developing technology such as wind and solar, on the other. Fewer non-specialists know that widespread solar technology includes two distinct technologies: concentrating solar power (CSP) and photovoltaic (PV).

PV is cheaper and less CSP, though PV has a lower capacity factor and lacks storage. Here, the capacity factor is the relative measure of utilization of rated (maximum) capacity for electricity generation. Importantly, CSP and PV are often considered in combination where PV brings benefits of distribution while CSP ensures accumulation of energy for stable supply in periods when irradiation is low. PV is further classified into utility-scale solar PV for larger projects; and residential and commercial sector rooftop solar PV for smaller or distributed systems. Also, onshore and offshore wind technologies are distinguished based on whether turbines are located in seas or lands. Utility-scale PV is cheaper but requires larger initial investments. Rooftop PV could cost higher than utility-scale PV but provides wider distribution and encourages the participation of individual households. Finally, solar thermal heating and cooling for industrial processing and residential systems constitute significant capacity globally, but it is not considered in detail in this report because of the focus on electricity.

Offshore wind farms can be built only in coastal areas and are understandably more expensive to build (high installed cost) and operate, but they provide higher efficiency (capacity factor) and stable supply due to stronger winds offshore (see Figure 3). Offshore wind represents about one-tenth of total wind capacity in the world mostly concentrated in coastal areas of Western Europe and Asia. Offshore wind, while of interest for coastal areas of Kazakhstan and Turkmenistan in the distant future, is not considered in subsequent sections of this report as the relevant countries currently lack infrastructure and expertise, and other resources to economically develop this type of renewables.

Bioenergy and geothermal are more diverse in the types of used technology. They have high capacity factors but require special natural resources that are challenging to explore (geothermal) or deliver within the proximity of a power plant (biofuel). Gas from landfills and renewable municipal waste is already mature technology that addresses both ecological and energy concerns.

Understandably, ocean and geothermal power are excluded from deep analysis in this report for the Central Asian region where natural and other resources in this renewable are negligible. Furthermore, hydropower and bioenergy as mature forms of renewables with smaller changes in technology and costs are considered mostly from the perspective of complementing and replacing wind and solar power when appropriate. Hence the main focus

would be on rapidly growing wind and especially solar technology (they are often collectively referred to as VRE - variable renewable electricity).

It is important to understand that fossil and renewable technologies often complement one another rather than compete (CSP and PV are a good example). Virtually no country envisions a total of exclusion fossil from the energy mix soon due to cost and stability considerations. The economic life of most projects in wind, solar, and geothermal renewables is 25 years – lower than for hydropower (30 years) but higher than for biofuel (20 years) (IRENA 2020). Thus decisions made on power plants are long-term and hard to adjust once implementation starts: relevant factor for Central Asia where modernization of fossil and hydropower plants is underway.

Financing renewable projects and shift in energy outlook

Improving technologies, economies of scale, competitive supply chains, and developer experience led to renewable power becoming the lowest-cost option for new capacity in almost all parts of the world (IRENA 2020). As of 2019, renewables accounted for over 70% of all new capacity additions. Between 2010 and 2019, cost (LCOE) of utility-scale PV fell 82%, CSP fell 47%, onshore wind 39%, and offshore wind 29% (IRENA 2020). The cost for the mature technologies of bioenergy, geothermal, and hydropower has not changed considerably relative to solar and wind. Traditionally important hydropower remained highly competitive though: most capacity commissioned in 2019 had power costs lower than the cheapest new fossil fuel-fired projects.

The common modern methodology for estimation of renewable costs usually involves the average lifetime levelised cost of electricity generation or LCOE. LCOE calculation formula includes the sum of all major costs (including investment expenditures, fuel expenditures operations, and maintenance expenditures in any year of the renewable project) divided by the sum of electricity generation and discounted by discount rate (cost of financing); all those parameters are taken over the life of the system. This method reveals the crucial role that financing terms play in decisions regarding investments in renewables. The weighted average cost of capital (real) for renewable projects is assumed 7.5% in Organisation for Economic Cooperation and Development (OECD) and China, countries with low borrowing costs are low risks (meaning relatively stable regulatory and economic

policies). The same cost is already assumed 10% for the rest of the world (IRENA 2020). This fact alone demonstrates how high initial costs, regional risks, and lack of competitiveness discourage renewable developments in areas such as Central Asia. Interestingly, soft costs including not only finance but also permits, project rights, compliance with incentive applications, environmental, and other regulations constitute a considerable share of costs of renewables such as PV (IRENA 2020). Official Development Assistance, foreign investments, and the private sector, therefore, should be combined with appropriate governmental funding, legislation, and other policies. The important role of legislation and investments is discussed later in detail.

The experience of leading and largest countries in financing renewables is interesting to consider first. China is the major importer of fossil for post-Soviet countries that leads the world in installed coal, wind, solar capacity, and nuclear power. If renewables trends continue, over 60% of China's electricity will come from non-fossil sources by 2030 at 11% lower cost; but the share of gas as a relatively clean fossil fuel in total energy capacity should remain stable within 7 – 11% (He et al 2020). China's pledge to cut its net carbon emissions to zero by 2060 would further reduce the use of fossil in electricity and transportation while offsetting remaining emissions through carbon capture or planting forests (Normile 2020). The EU aims to achieve net-zero greenhouse gas emissions already by 2050 as an objective of the European Green Deal (European Commission 2020). Japan, UK, and other developed countries put similar targets by 2050; the US is a notable exception where currently only parts of the country such as California made such targets, but it could change soon under the new administration after 2020 (Darby and Gerretsen 2019). India, a potential future importer of energy resources from Central Asia, recently achieved the lowest renewable costs in the entire world (IRENA 2020). The performance of renewables is all more impressive considering the huge subsidies fossils still receive disproportionally relative to wind and sun capacity in all the major countries. The entry of an increasing number of businesses to the renewables market in the 2010s when high demand initially drove considerable profit margins recently contributed to more competitive prices for related equipment and services in international markets where suppliers actively try to enter new markets with untapped potential such as Central Asia. The difference in observed capacity factors for PV depending on location globally motivates the move of installed new solar capacity to sunny locations, which again favors Central Asia (IRENA 2020).

The funding remains an issue for many developing countries in expanding all types of renewables outside decentralized PV. Formerly centralized economies of Central Asia still tend to favor grand projects showing sizable investments and scale. To illustrate large-scale renewable capacity costs, the following projects in comparator countries are worth mentioning. The largest renewable asset finance in 2019 was a $3.9 billion deal to construct 700MW solar thermal (tower and parabolic CSP) plant in UAE (IRENA 2020). The largest deal to finance renewable projects among post-Soviet countries in 2019 was 750MW onshore wind in Ukraine at $1 billion (IRENA 2020). Baku Waste-to-Energy Plant in Azerbaijan inaugurated in 2012 presents an interesting example of bioenergy in the former Soviet republic (IRENA 2020). The plant had an estimated cost of EUR 346 million, 20 - year operation, and 500 000 tons of annual capacity of municipal waste per year (IRENA 2019). Such biopower plants bring the combined benefit of energy and heat supply as well as processing solid household waste. Overall, large plants can deliver higher efficiency and stability in power supply, but risky financing terms involving foreign investments can come at risks as discussed later.

Though information on specific Central Asian countries is scarce in the extant literature, relevant information on comparator countries and regions is valuable for purposes of comparisons. For instance, regional information on Central Asian renewables costs is often included in the IRENA report as the part of Other Asia category, which includes Asian countries minus China and India. Obviously, it is problematic to draw accurate conclusions on Turkmenistan, Tajikistan, Uzbekistan, Kazakhstan, and the Kyrgyz Republic, when they are included in the diverse geographical area encompassing such different countries as Afghanistan, Bangladesh, Indonesia, Japan, Malaysia, Mongolia, Myanmar, Nepal, Pakistan, Philippines, Singapore, Sri Lanka, Thailand, Viet Nam, South, and North Korea. Nevertheless, regional data on areas such as post-Soviet and Other Asia are useful for evaluation of what can be achieved by states with comparable resources. The unfavorable renewable dynamic trend in Other Asia revealed by IRENA 2020 with costs falling less sharply and rapidly than in other regions could be partially explained with late entry, just like in the case of the Central Asian part of the area. Eurasia is another exemplary area where post-Soviet Ukraine depending on hydrocarbon imports achieved remarkable scale and low cost of utility-scale PV. Even the energy-rich countries such as Russia and Gulf states actively invest in renewables in the realization that hydrocarbon dependence cannot last long (Ajadi et

al 2020; IRENA 2020). Arab states rich in hydrocarbon but with historically low to negligible renewable energy use now set ambitious targets to develop renewables with UAE leading the Middle East in recent renewable development (REN21 Secretariat 2020). Certain countries including those in Central Asia could be already missing renewable opportunities due to various reasons, and they should be more active in catching up.

Potential of non-hydro renewables in Central Asia

As Figures 1 and 3 illustrate, Central Asia has on average higher potential for the generation of electricity from both onshore wind and sun as compared to the rest of Eurasia. North-Western parts of Central Asia encompassing Kazakhstan, Uzbekistan, and Turkmenistan, in particular, seem to have a larger potential for wind (Figure 3). The larger part of Central Asia has a high number of sunny hours with close to annual 300 sunny days meaning the decent potential for a stable uninterrupted supply of solar power as Figure 2 shows (de Jong et al 2017). This is particularly relevant for Uzbekistan, Tajikistan, and Kyrgyz Republic – countries prone to seasonal or weather-related fluctuations in energy supply (EIU 2017). The potential of the region for PV capacity looks higher than other renewable technology due to lower costs and complexities compared to CSP and wind. Overall, wind and PV in Kazakhstan, PV, and biogas in Uzbekistan, small hydropower in the Kyrgyz Republic, small hydropower and PV in Tajikistan, and PV in Turkmenistan have the higher prospects (Nabiyeva 2018).

Floating solar (FPV) installations tethered to the bottom of the reservoir or canal seems especially promising for Central Asia with its extensive network of irrigational channels and dams. Not only does floating photovoltaic technology requires fewer resources of land and cooling energy, it importantly helps improve water quality (by algae control) and save water in the region with scarce water resources (Daley 2019). Manufacturers of floating solar plants claim they can save 80% of the evaporation of the covered surface (more than 20000 m3/year/ha) in arid areas where water is used for hydroelectric or irrigation purposes; moreover, large volumes of water used in the cleaning of installed solar arrays can be saved too (Hodgins 2020). Floating solar is compact, easy to maintain, and remove, but engineers still have to assess the impact of the new technology on wildlife and develop effective measures against corrosion, high winds, and waves so the installations can last for at least 25

years as other renewables (Daley 2019). Hydro and floating solar can be combined in areas of dams and other large water structures.

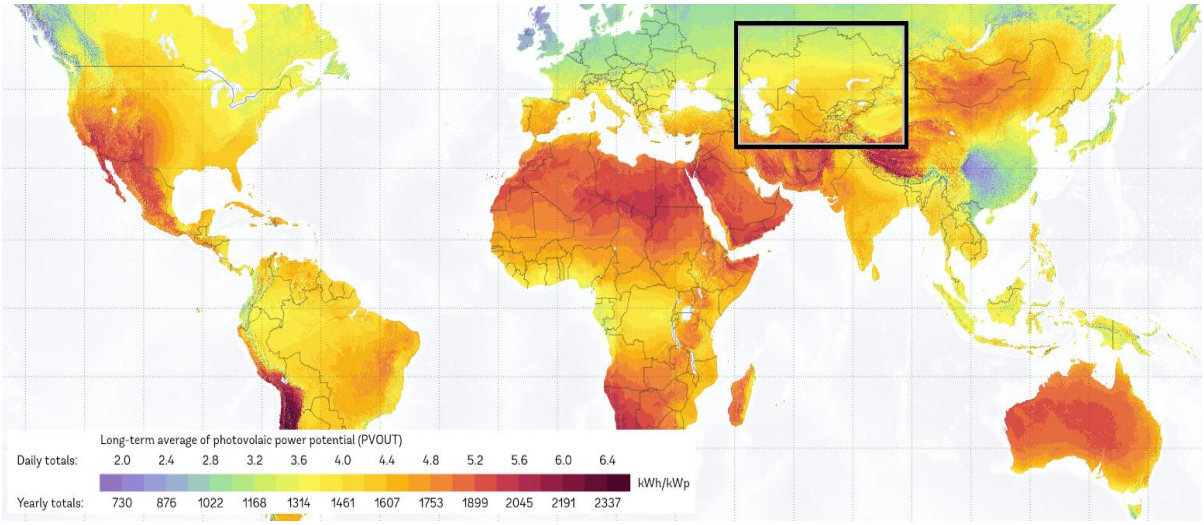


Figure 1. *Map of long-term average for photovoltaic power potential PVOUT in kWh/kWp (Source: adapted from Solargis (2020)).*

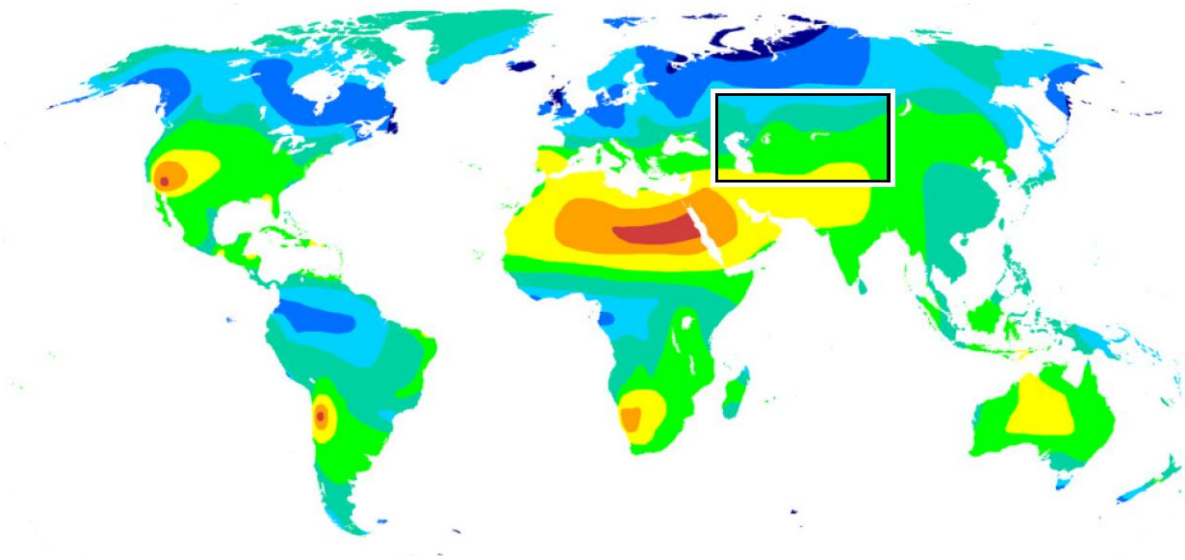


Figure 2. *The annual number of sunny hours in Central Asian countries relative to the world (Source: adapted from de Jong et al (2020)).*

Since there are fewer technologies that can be readily adapted in any region of the world in bioenergy relative to wind and gas, this is another perspective area for local renewable R&D in Central Asia. Worldwide, a variety of technologies were adapted for bioenergy prevalent in

each region: rice husks in China, bagasse in India, and wood waste in Europe and America. Traditional forms of biofuel have long been used by the local population in Central Asia: wood, dung, and other bioenergy used in certain areas. Since traditional biofuel presents pollution, health, and deforestation hazards, the focus should shift to new perspective technologies (advanced biofuels). Landfill gas use is widespread in many regions of the world, but its potential is yet to be realized in Central Asia with its waste growing proportional to population. Aside from municipal waste, agricultural waste in the region has potential as feedstock, which is limited but can nevertheless be exploited effectively. Since Central Asian countries do not have significant feedstock for biofuel from sources common in other regions, municipal and cotton waste present high interest for future development.

Finally, geothermal and wave energy does not seem viable in the near future due to its high costs and complexities even though the region has areas with potential sources for this underutilized renewable.

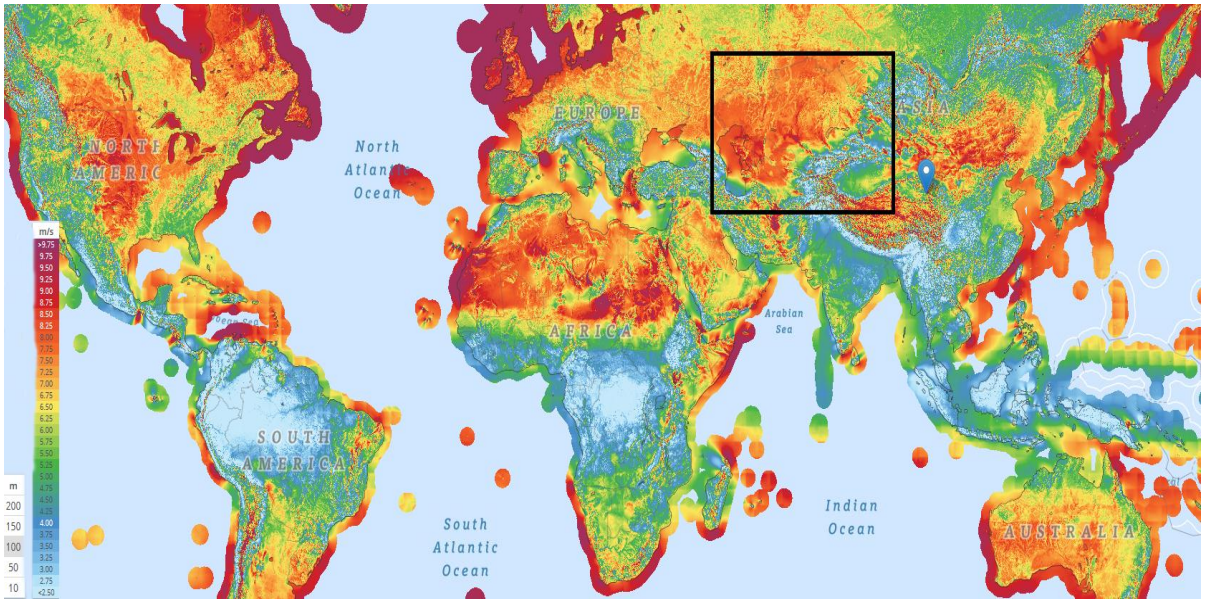


Figure 3. *Global wind potential (Source: adapted from Energydata.info (2020)).*

Possible reasons for the underutilized potential of wind and solar power in Central Asia

Up until the end of the 2020s, Central Asian countries mostly limited non-hydro renewable actions to participation in related conferences, exhibitions, declarations, and initial legislative steps (Marques 2018). They also showed limited participation in activities of technical

organizations and initiatives such as IRENA as corresponding reports indicate. This approach to renewables is changing but does not seem proactive enough. Figure 4 illustrates just how negligible the share of non-hydro renewables has been in the region despite various supporting measures outlined in Table 1. Unfortunately, there were no specific targets and policies related to renewables in transport and heating/cooling sectors known as of 2019 (REN21 Secretariat 2020). Therefore, further discussion is limited to the main area of renewable energy – electricity power.

The energy ministries of countries in Central Asia have committed to the more active promotion of renewable energy since 2017 with IRENA support (Nabiyeva 2018). Still, Kazakhstan seems to lead the region in new wind and solar developments as the country does in many other socio-economic indicators including ease of doing business (Marques 2018; Cohen 2020). Increasing interest in the region toward renewables could also partially be motivated by the country's image and desire to follow fashionable global trends in national policies. Some observers even voiced concern that the interest could be driven by the state showcasing projects that have weak relation to the real market needs (Nabiyeva 2018). Meanwhile, neighboring Russia, Ukraine, and Azerbaijan had already implemented advanced forms of cooperation, assessments, and several large projects on a national scale. Post-Soviet Ukraine traditionally relying on hydrocarbon imports increased the share of wind and solar in total energy supply almost 50-fold by adding renewable capacity notable even on a global scale in the period 2010 to 2020 (IRENA 2020, IEA 2020). Ukraine was the largest post-Soviet country in 2019 in terms of renewables investment with $3.4 billion and 56% growth in 2018 (Ajadi et al 2020). Russian Federation came second with $2.3 billion and 76%. As a relevant example of another post-Soviet country relying on hydrocarbon exports, neighboring Azerbaijan increased solar and wind share ten-fold in 2010 – 2020 and already completed formal Renewables Readiness Assessment (RRA) with the involvement of IRENA, an important step toward actual deployment of renewables capacity (IRENA 2020).

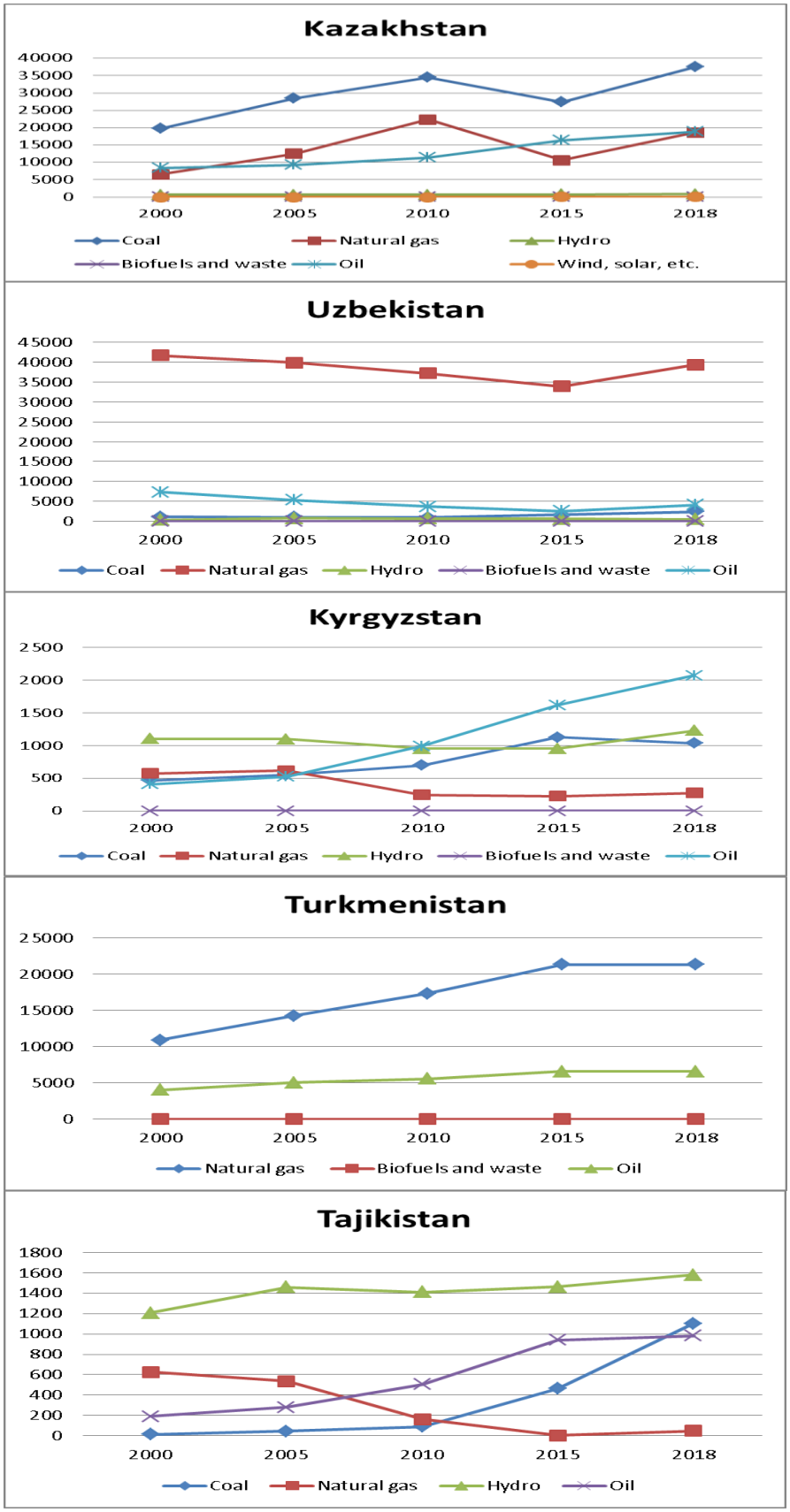


Figure 4. Total energy supply (TES, *ktoe*) by source in Central Asia 2000-2018 (IEA 2020).

Table 1. Targets and policies in Central Asian renewables as of 2019 (REN21 Secretariat 2020).

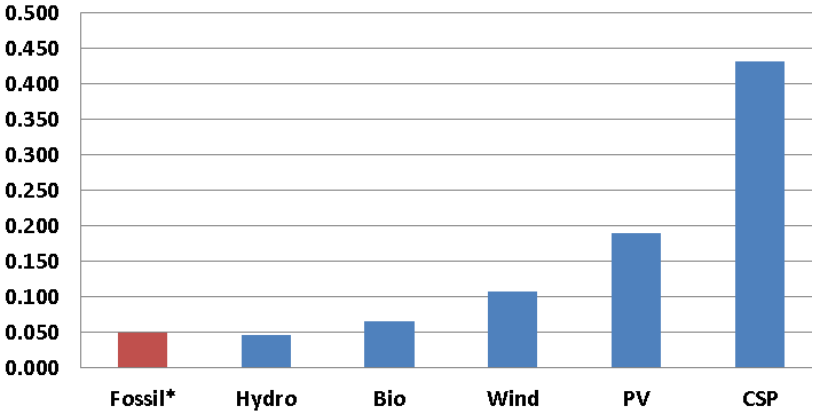
	Kazakhstan	**Uzbekistan**	**Kyrgyz Republic**	**Turkmenistan**	**Tajikistan**
Capacity targets	-Bio-power 15.05 MW at three stations by 2020 -Hydropower 539 MW at 41 stations by 2020 -Solar power 713.5 MW at 28 plants by 2020 -Wind power 1,787 MW at 34 stations by 2020	-Solar PV 157.7 MW by 2019; 382.5 by 2020; 601.9 by 2021; 1.24 GW by 2025 -Wind power 102 MW by 2021; 302 MW by 2025			Hydropower (small-scale) 100 MW by 2020
Feed-in Electricity Policies	In 2013				Date unknown
Tradable REC	Available				
Tendering	Available	Available			
Investment or production tax credits		Available			
Public investment, loans, grants, capital subsidies or rebates	Available				

Table 1 illustrates low to moderate levels of support for development in renewables in Central Asia that does not seem impressive when considering the variety of measures the majority of developing countries have already taken (REN21 Secretariat 2020). Installed non-hydro capacity seems meager: even in Kazakhstan, the leader in non-hydro renewables in the region, wind, and solar was below one percent in 2018 (Figure 4). No precise studies were made on reasons for such inadequate use of renewables, but the most obvious explanation could be the economic, technological, and political attractiveness of fossil fuel – its low cost, less variable

output, and widespread subsidies in Central Asia (Nabiyeva 2020). Table 2 suggests consumers in Central Asia could have access to the cheapest electricity in the world, though the actual cost could be even lower depending on the season, industry, market exchange rates, and quotas of nearly free electricity in countries like Turkmenistan. Heavy government subsidies in the region undoubtedly distort market prices in the region (IEA 2020). Even without the effect of subsidies, actual electricity costs based on fossil and hydro are still probably among the lowest in the world. In fact, so cheap is the cost of electricity ($0.01 to $0.03 per kWh from private power plants in Kazakhstan for foreign businesses) that bitcoin miners abroad consider moving to Central Asia (Redman 2020).

Prices that consumers pay in Central Asia for electricity seem to be much below the objective measure of cheapest LCOE when comparing Figure 5 and Table 2 using conservative estimates – cost difference of up to five times. Figure 5 shows comparisons of renewable cost in Central Asia based on assumption that fossil power is the cheapest and non-hydro renewables are the most expensive in the region with approximate estimates based on data ranges of LCOE provided by IRENA in 2019. This rather restrictive assumption was made due to a shortage of specific project data on all Central Asian countries. However, it seems to be supported by the cost of existing projects in the region. For instance, the costs for PV (residential systems up to 10 kW) around 2018 were €1600-1800 in Kazakhstan - almost 50% more expensive than €1200-1300 in Germany due to higher customs, transport, and guarantee costs relative to Europe (Nabiyeva 2018). It seems Central Asia is among the few remaining regions of the world where traditional energy is roughly equal or slightly lower than that of modern renewables (IRENA 2020). As already mentioned, the cost of fossil energy globally exceeds renewables for over half of recent projects (IRENA 2020). Furthermore, LCOE does not sufficiently take into account pollution, health, and other external costs of fossil. Given the relentless decline of wind and solar costs, Central Asia cannot afford to stay complacent with almost 100% reliance on fossil and hydropower.

In addition to the low cost of fossil and heavy subsidies, logistical challenges, lack of expertise, financing limitations, inadequate linkage to currency, and opposition from the fossil industry all could play a role (Nabiyeva 2018). Furthermore, conjecture can be made about other likely reasons for underdeveloped renewables such as lack of knowledge about the true potential of renewables, prevalence of old conservative methods of costing, and lower priority of ecological problems for the regional governments that renewables could help solve.



Note: assuming the low-cost (LCOE in USD/kWh) range for fossil; the weighted average for mature renewables – hydro and bio; and 95th percentile for variable renewables – solar and wind.

Figure 5. Cost comparisons of cheapest fossil, average hydro, average bio, and the most expensive non-hydro renewables in 2019 based on © IRENA estimates *(Source: IRENA 2020)*

Table 2. Estimates of typical electricity prices in post-Soviet countries.

Country	Electricity prices for business in 2019 (kWh, $)	Electricity prices for households in 2019 (kWh, $)
Turkmenistan	0.010	0.007
Tajikistan	-	0.015
Kyrgyz Republic	0.020	0.010
Uzbekistan	0.030	0.015
Kazakhstan	0.050	0.040
Azerbaijan	0.050	0.040
Georgia	0.050	0.060
Armenia	0.070	0.080
Ukraine	0.080	0.050
Russia	0.080	0.060
Moldova	0.090	0.110
Belarus	0.090	0.080
Estonia	0.110	0.190
Lithuania	0.130	0.180
Latvia	0.150	0.190

** Sources: GlobalPetrolPrices.com for most countries; some estimates were based on alternative sources that could be outdated: Enerdata (2020) for Uzbekistan, Gassner (2017) for the Kyrgyz Republic, Energypedia (2020) for Tajikistan, and local survey for Turkmenistan.*

Logistical challenges remain in the transportation and transmission networks for flows of materials and energy-related to renewables. Policymakers in Central Asia are well aware of the fact that fossil energy in the region is not only cheaper but also less variable technology that requires lower storage relative to bio and solar energy. Therefore, non-hydro renewables can effectively compete with fossil only in limited areas. Rural, desert, and mountainous areas have underserved populations and economies in terms of energy supply. Those locations have land available for renewable projects, but they often lack transmission and road infrastructure. Decentralized and autonomous PV systems that do not require transmission to remote areas seem suitable in many cases. CSP and wind turbine components appear challenging to deliver and install in landlocked countries of Central Asia with underdeveloped infrastructure to transport and mount the nonstandard general cargo.

A long-term solution to the issue of expertise and disadvantaged geographical location for equipment delivery and installation would be to set up local manufacturing of renewable components with direct foreign investments. Such local production would spur the development of renewables in the entire region and bring much-needed expertise. Kazakhstan and Uzbekistan with their current investment climate, scale, and resources (importantly, including metals and machining) could be particularly attractive for manufacturing wind turbines, though all countries seem to have sufficient resources to supply energy and raw materials for manufacturing cheap PV crystalline silicon modules. The recent trend for manufacturers of renewable components is to move production to countries with lower costs (IRENA 2020). The Central Asian countries should consider providing the best conditions for investors in order to gain the competitive advantage of hosting such manufacturing capacities in the future. The importance of foreign partners and legal support is further discussed in the following section.

One of the issues that could hamper renewable development in Central Asia is insufficient human resources and lack of expertise. The region lagged behind most other areas of Eurasia in innovations and R&D output (UNESCO 2015). In accounting for renewable costs, state agencies should use modern methods of costing projects using LCOE and up-to-date parameters instead of obsolete calculation techniques that likely underestimate long-term values. Quantitative techniques in renewables such as SWITCH (capacity expansion model for the electricity sector) widely used by planners and researchers in advanced countries

should aid comprehensive analysis for decision-making in the future energy mix of the region. The region has a history of renewable research though. The reputed Sun Institute and Desert Institute within the Turkmen socialistic republic were established back in Soviet-era (Sun institute was closed temporarily after independence and then reopened in 2009). Experimental work on using solar and wind power for water purification in pastures within the desert was conducted in the Central Karakum desert since the 1970s and continued till the mid-1990s (Kolodin and Chariev 1996). Such projects however were limited in scale due to the high costs of renewables at that time. The priority of water (desalination) and energy supply for residents and organizations located in remote areas utilizing a decentralized network of combined solar-wind systems using the latest technology with lower costs could become a starting point for the revival of R&D in renewables in the region. Kazakh research and development could help take advantage of agricultural waste from vast fields in the country provided logistical issues, the big concern for biofuels, are solved cost-effectively. Using cotton biomass is another perspective area for suitable countries such as Uzbekistan and Turkmenistan. Technology for converting solid gin trash and on-farm cotton residues to energy is still in its infancy (Hamawand 2016). Uzbek and Turkmen researchers could study how using cotton stalks could generate extra revenue from the massive biomass of the plant in the countries. The share of biomass in the energy mix is still likely to remain low due to the inherent logistical challenges of the technology in collecting scarce feedstock from vast areas. In addition to R&D, the education systems of Central Asian countries would have to adapt, as they currently seem to offer little engineering and managerial training in all areas of non-hydro renewables. The International Solar Energy Institute in Tashkent was launched with the support of ADB in 2012 to address the growing need for solar energy training (Nabiyeva 2018).

Most countries of the world will undoubtedly continue efforts to reduce dependence on imports of fossil fuel by expanding the share of wind and solar renewables. The commodity-exporting countries of Central Asia need to reassess both the internal and external impact of renewables. Coal, gas, and hydropower still remained the major sources of energy in Central Asia, and the volume of coal-generated energy continues to expand in capacity and output. The majority of power plants in the region are old and would need replacement in the near future. And here lies the right timing for tapping the renewable potential that was not realized previously due to economic reasons. Not only will the expansion of renewable

capacity instead of fossil help reduce the cost of energy mix; it will have multiple benefits for ecology, emission targets, wider distribution, security, and resilience of electricity supply.

Foreign investment opportunities in renewables for Central Asian economies

In this section, major players that could play a significant role in developing Central Asian renewables are discussed. All neighboring countries, other post-Soviet countries, and prominent global leaders present in the region such USA, Japan, South Korea, and India could undoubtedly play their role in future developments in the region. Nevertheless, China, Russia, European Union (EU) countries, and institutional investors are all considered especially relevant for Central Asia due to their relatively high influence in the region.

China played a very positive role in the development of renewables driving down renewable costs and increasing expertise in related manufacturing (The Economist 2020). Chinese companies could seem natural partners in developing renewables with their expertise and manufacturing prowess. About half of $575 billion promised under China's Belt and Road Initiative as of 2019 is planned in energy projects, where Chinese companies such as State Grid (the world's biggest utility) and Three Gorges will invest more in renewables abroad (The Economist 2020). Especially in solar power, Chinese businesses offer integrated manufacturing and sales capacities unmatched by other firms in the global market. Such dependence of the world on China is huge to the extent that it worries Western partners: the country produces over 70% of the solar modules, hosts nearly half the manufacturing capacity for wind turbines, and dominates the supply chain for batteries (The Economist 2020). State-backed Chinese investors could be considered first in large-scale projects by governments in Central Asia due to the expertise and market power in renewables despite concerns about low transparency and unfavorable financing terms. As an example, AIIB builds the largest wind power plant in Kazakhstan and the region (Xinhua 2019). To summarize, Chinese investments could potentially play a very important role in the development of renewables with their finance and expertise, but the governments should exercise particular caution in negotiating terms of any agreements especially in large and long term projects in order to avoid excessive dependence on single big partner and difficulties that other developing countries involved in the massive Belt and Road Initiative already experienced.

Besides China, Russia could become an attractive partner in renewable investments. Historical, cultural, geographical, and language proximity could make Russian businesses suitable candidates for developing renewables and supporting infrastructure. The Russian-led Eurasian Economic Union (EEU) can greatly facilitate investments and customs between member states in the region. There is an issue, however: existing Russian companies lack experience and efficiency in the field of renewable technology compared to other major players. For instance, the cost of utility-scale PV renewables in Russia exceeded averages for other regions where major projects were implemented (IRENA 2020). Operations in distant areas with harsh climatic and other geographic conditions partially explain the high costs, but other factors such as low efficiency and transparency could play a role.

Countries and organizations in the EU have considerable expertise and financial resources to play a more active role in developing Central Asian renewables. European companies are highly competitive in renewable (wind in particular) technology and sales on the global level. European support has provided a market for Siemens Gamesa (the world's top wind turbine manufacturers), Enel (the single largest investor in wind and solar in developing countries based in Italy), Iberdrola (Spain), Orsted (world's top developer of offshore wind-based in Denmark), Electricité de France and Engie (France) and other influential companies in renewables that are all operating on a global scale (The Economist 2020). EU funding within Horizon Europe and other frameworks could greatly facilitate renewable developments. Within the EU, the Baltic States historically had closer economic and cultural ties with certain countries in Central Asia that could be relevant for partnership. For instance, Latvia with its Russian-speaking businessmen and expertise in biofuels could seem natural partners in developing this specific type of renewables in the region.

Finally, the potential role of reputable international organizations such as the Asian Development Bank (ADB), the World Bank, and the European Bank for Reconstruction and Development (EBRD) cannot be overestimated. Sustainability, the private sector, and vulnerable populations are high on the agenda of such influential institutional investors in Central Asian economies. Leveraging favorable financing terms together with rigorous requirements towards transparency and environmental friendliness, they could make a crucial contribution to the shift in the region to sustainable post-pandemic growth now that governments of the Central Asian countries face socio-economic uncertainty. EBRD, the largest institutional investor in Central Asia, prioritizes transition and promotion to green

energy in Kazakstan and Uzbekistan (EBRD 2018). The World Bank Group Scaling Solar Program appears as an attractive source of funding for the region (The World Bank 2020). Funding and implementing renewables projects of various scales with the involvement of a broad range of stakeholders (including foreign companies from the EU, China, and Russia) with high standards of social responsibility would reduce risks of giving up the sector to less stringent practices damaging the local population in the long run. In doing so, both the populations of the countries and the international partners could achieve a win-win situation of getting much-needed investments but without compromising on sustainability goals. While the role of international institutions is crucial, over-reliance should be avoided in the long term as domestic financial markets should develop sufficiently for much-needed diversification (Cohen 2020).

The previous experience demonstrated that the implementation of complex projects in the participation of foreign partners could be challenging on the regional scale in particular. The massive CASA-100 funded by the World Bank Group ($526.5m), Islamic Development Bank ($155m), EBRD ($110m), European Investment Bank (EIB, $180m), UK Department for International Development, Afghanistan Reconstruction Trust Fund ($40m), USAID ($11.5m), UK Department for International Development ($46m), Pakistan ($101m) could benefit the entire region (NS Energy 2020). It was approved in 2014, but actual operations could start from 2022 with the active participation of only two Central Asian countries - Kyrgyz Republic and Tajikistan. (NS Energy 2020). The implementation of projects including 100 MW Samarkand Solar, the first on-grid PV park in the country, was to be financed by a $110 million ADB loan; but it was postponed and then canceled after the reconsideration by the government of Uzbekistan in 2017 (Nabiyeva 2018). Additional examples of investment projects as well as corresponding challenges are considered further in the next section.

Legislation of Central Asian countries and renewable development

Historical developments demonstrated how government regulations were critical for the establishment of sustainable energy. Feed-in tariffs (green tariffs) and later flexible pricing mechanisms such as Power Purchase Agreements (PPA) and auctions were instrumental in supporting renewable growth before it reached the current competitive state in major countries. The feed-in tariff is a favourable rate paid for electricity fed back into the electricity

grid from the source of renewable electricity generation. The countries of Central Asia have only recently started taking steps in the field of legal regulation for renewable energy sources, improving energy efficiency, adoption of programs, and strategies to increase the share of renewable energy. The process of forming a legal basis for the implementation of the measures for energy conservation, efficient operation of enterprises in the expansion of the share of renewable energy sources in the fuel and energy balance is underway in all five Central Asian countries. All countries in Central Asia are part of the EU4Energy Programme focused on evidence-based policymaking in the energy sector. They were advised by the International Energy Agency to improve energy efficiency and slowly remove widespread subsidies for further investment and expansion of domestic energy resources. Table 3 and the following text list some existing and previous legislation related to energy efficiency and renewable (IEA 2020). Since the number of renewable projects in the region is relatively small, the most significant facilities planned or implemented in each country are briefly discussed below together with brief information on relevant legislation.

Kazakhstan is leading Central Asia in non-hydro renewables with legislative support and the share of alternative energy in the energy mix almost reaching one percent by 2020. This figure is planned to increase to 30% by 2030, and to 50% by 2050 – an ambitious target for the region (Chachine 2019). Kazakhstan was the only Central Asian country featuring in the list of top 30 investors in renewables in the world as of 2019 with $0.8 billion and 58% growth in 2018 (Ajadi et al 2020). Since 2009 favorable conditions have been created at the legislative level including the introduction of fixed tariffs, guaranteed purchase of energy generated from renewable energy sources, and elimination of tax burden. The country is still heavily reliant on coal in the energy mix, and expansion of the gas pipeline network remains a priority in order to expand access (IEA 2020). Kazakhstan appears to actively adapt to national energy and foreign investment strategies already. The Electric Power Sector Law and the Law on Supporting Renewable Energy Sources (RES Law) provide buying all generated renewable power at feed-in tariffs by the Center of Financial Settlement (Chachine 2019). The country is implementing various new renewable projects in the participation of EBRD, ENI, GE, and Chinese JinkoSolar Holding (Marques 2018). The 100-megawatt wind power plant (largest of its kind in Central Asia) in Zhambyl with 319 GWh annually is operated within Zhanatas Wind-Power Station Limited Liability Partnership by China Power International Holding Limited, a subsidiary of State Power Investment Corporation; this is also the first

project funded by the Asian Infrastructure Investment Bank (AIIB).in the country with 46.7 million loans in total $136 million total estimated cost (Xinhua 2019). The EBRD made the largest investments in Kazakhstan's green economy - over USD 8.85 billion through 254 projects including the largest solar (Burnoye Solar Plant), wind (Yereymentau Wind Farm), transportation, and switch from coal to renewables (Cohen 2020).

A number of renewable initiatives including decentralized PV (private rooftop) have been approved in Uzbekistan recently (Bellini 2020). Renewables could play an increasing role in the diversification of the energy sector of Uzbekistan when modernizing the aging infrastructure. Losses, overuse, and financing remain problematic to meet the domestic demand of Uzbekistan's growing economy and population with energy that currently heavily relies on gas (IEA 2020). In addition, a law on public-private partnerships has been adopted, and a draft law on the use of renewable energy sources was under consideration. The State Action Plan on Renewable Energy includes 810 projects with a total value of $5.3 billion for the period 2017-2025; however, investors could become cautious after the experience of PV projects that were planned by ADB since 2013 but canceled at the government request in 2017 (Nabiyeva 2018). Nevertheless, more cooperation with international companies and feasibility studies are currently being developed. The World Bank and International Finance Corporation Boards of Executive Directors approved the Navoi Scaling Solar Independent Power Producer (IPP) Project in 2020 under the World Bank Group Scaling Solar Program. The project with competitively selected private investment to connect the first solar plant of 100-megawatt capacity to the national electricity network is the first World Bank guarantee operation in Uzbekistan (The World Bank 2020). Canadian developer SkyPower Global signed an agreement with state-owned JSC Uzbekenergo power utility in 2018 to invest a staggering $1.3 billion, construct, and operate several large-scale PV plants with a combined capacity of 1 GW (Nabiyeva 2018).

Development of the electric power industry, with the exploration of the potential use of alternative sources of energy: sun, wind, geothermal, and biogas was determined priority areas for national R&D in Turkmenistan since 2010 (UNESCO 2015). More recently, smaller water supply and purification systems driven by PV power were installed in villages of Karakum within UNDP cooperation with the Sun Institute (UNDP 2020). Turkmenistan has yet to develop a much-needed capacity for renewables in remote desert areas. The country adopted the Energy Saving Program for 2018-2024, which considers an increase in the share

of renewable and non-traditional energy sources, alternative fuels, and secondary energy resources in the balance of Turkmenistan; development and implementation of innovative technologies in the field of renewable energy; creation of new generating capacities based on the use of renewable energy sources. The implementation of the Program involves strengthening government regulations in the field of energy-saving. This would require the adoption of a large number of regulatory legal acts, including the preparation of the Law on Alternative Energy Sources, as well as the necessary standards, regulations, and rules for their use. The Interdepartmental Working Group was established to develop a National Strategy for the Development of Renewable Energy. The joint project of the UNDP and the Ministry of Agriculture and Environmental Protection of Turkmenistan "Sustainable Cities in Turkmenistan: Integrated Green Urban Development in Ashgabat and Awazaproject" took an active part in the development of drafts of two new Laws of Turkmenistan - "On Renewable Energy Sources" and "On Energy Efficiency and Energy Saving", in the National Strategy for the Development of Renewable Energy (United Nations in Turkmenistan 2020). The National Strategy of Turkmenistan on Climate Change (2019) provides for a set of measures for the implementation of renewable energy sources: support for R&D and testing of technologies for renewable and alternative energy; introduction of small and medium-sized installations of renewable in remote and sparsely populated areas; introduction of production facilities and increasing the share of renewable energy in the country's energy mix; creating economic incentives for the use of alternative energy sources; disseminating knowledge about renewables, and so forth. The Law of Turkmenistan on Electricity (2014) provides for the development and implementation of measures for the use of renewables. In 2018, Turkmenistan became a member of the International Renewable Energy Agency (IRENA), which involves a plan of bilateral and multilateral events for 2019-2023 to develop further cooperation with IRENA. The support of potential private investors is considered by the Law on State Support of Small and Medium Business, the Law on Innovation Activities, and the planned law on the joint state and private partnership. The country would have to improve transparency in statistics and information-sharing among government and international organizations in order to further streamline the energy sector governance (IEA 2020).

In the Kyrgyz Republic, a legal framework for renewable energy was being developed to adopt a national energy program, which includes a provision on the development of renewable energy sources, their wider use in the power supply of the rural population, and

autonomous facilities located in mountainous regions of the republic. Still, not many pieces of legislation on renewables were adopted in the past, and there seems to be low interest in non-hydro renewables with the absence of significant projects in the field. There was little information known on specific targets or policies related to wind or solar as of 2019 (REN21 Secretariat 2020). The Kyrgyz Republic continues to rely on abundant and cheap hydro energy; however, the sector is based on an aging infrastructure that had significant losses (IEA 2020). Developing new cheaper capacity in non-hydro renewables could help address energy security concerns.

In Tajikistan, most of the electricity is still generated by hydroelectric power plants. The country is the renewables leader of the region with almost half of the energy generated by hydropower, and the share could increase further (REN 21 Secretariat 2020). Meanwhile, non-hydro renewables are insignificant. Tajikistan was the world's fifth-largest investor in hydropower additions below 50MW in 2019 (REN21 Secretariat). Tajikistan's energy sector experienced seasonal shortages in the past (IEA 2020). Despite several laws and programmes on renewables adopted in the past decade, any significant wind and solar capacity are yet to be built. The country has great potential for the development of solar and wind that could contribute to uninterrupted energy access - an important goal to benefit the population.

That the development of the energy sector of Central Asian countries requires the attraction of resources, as a capital-intensive industry is a notable fact. Central Asia had great potential to become an electricity generation hub, which remained largely unrealized due to the inability of independent governments to replicate the scale of legacy Soviet investments in thermal and hydropower power – system that currently suffers from seasonal shortages, poor integration of power grids, energy losses, and inadequate upgrade of transmission lines (EIU 2020). Unlike in Central Asia, equity, investments via the corporate R&D, public markets, venture capital, private equity, and asset financing have long been dominant in new renewable projects (Ajadi et al 2020). Governments in the region recognize the importance and necessity of attracting private sector capital to drive large-scale changes in the energy sector. This should be facilitated by the legislation on foreign investment, on public-private partnerships, which have already been adopted in the majority of the countries of the region. Private investment will reduce government spending, and the transfer of some functions to a private investor can improve the efficiency and quality of service, control costs, and increase the availability of new technologies and innovative management methods. At the same time, the

governments will likely keep the greatest power to exercise control and regulate the sector in the public interest, while supporting the business through favorable taxation and other benefits and guarantees. More support is needed for renewables in distributed systems, transport, and heating/cooling since Central Asia lags behind other regions in respective legislation (REN21 Secretariat 2020). However, attracting private investors could prove to be difficult since the energy sector is heavily monopolized by the state in most Central Asian countries. Therefore, one of the necessary conditions for renewable development is a gradual and adequate de-monopolization of the sector and the development of legislation to create conditions for commercial organizations for the generation, transmission, and distribution of electricity. Furthermore, it is important to provide an effective mechanism for the implementation of laws on renewables. This should also support joining consortiums under funding from major institutional investors as a multilateral alternative beneficial for stakeholders. Meanwhile, the state could preserve its role in general regulation to ease the concern of losing tight control over key sectors common for governments in the region. The countries in the region could start from state-backed pilot projects to gather experience and gradually shift to wider implementation in a wider area with various forms of ownership.

In all the countries of the region, a number of other factors that hinder the implementation of efficient energy measures remain such as geopolitical considerations, inadequate integration, tariff policies, high investment risks, and capital requirements. Harmonization of electricity transmission systems among the Central Asian countries alone could save up to US$5.2 billion over a five-year period, which is the target of the Central Asia Regional Co-operation (CAREC) programme by ADB (EIU 2020). Such important initiatives as the planned Central Asia South Asia Electricity Transmission and Trade Project (CASA-1000) were hindered in the past by lack of trade pricing mechanisms, low transparency, absence of harmonized regulatory and technical frameworks governing trade, institutional weaknesses in regional governance institutions, absence of regional transmission system regulator with authority over regional market, difficulty in aligning national and regional investments, differences in regulatory environments between countries, changes in a political framework, and concerns about national sovereignty and energy independence (Vallely 2017). Legal instruments coupled with non-hydro renewables should play a more important role in solving all these issues pertaining to inadequate legislative and political support.

Table 3. Examples of legislation related to renewables in Central Asian countries (IEA 2020).

Kazakstan	Uzbekistan	Kyrgyz Republic	Tajikistan	Turkmenistan
-Kazakhstan renewable energy auction, 2018 -Green Standard of Kazakhstan, 2017. -Energy Efficiency Classes for Buildings, Construction, and Structures, 2015. -On energy saving and energy efficiency increase, 2015. -Energy Management System - ISO 50001, 2014. -Fuel and Energy Development Concept 2030, 2014. -Green Energy Concept, 2013 -Kazakhstan Energy Conservation and Energy Efficiency Law, 2012. -The Law About Support the Use of Renewable Energy Sources (amended), 2009.	-Zero duty on import, 2019. -Resolution of the President of the Republic of Uzbekistan № PP 3012, 2017. -Resolution of the President of the Republic of Uzbekistan No. PP-2912, 2017. -Resolution on Further Development of Renewable Energy and Energy Efficiency 2017-2025, 2016. -Heating, ventilation and air conditioning, 1997.	-On Energy Performance of Buildings, 2011. -Law on Energy Savings, 1998.	-Energy Efficiency Standards on Power Sector and Appliances, 2014. -Sustainable Energy Action Plan in Somoniyon City, 2014 -On Energy Saving and Energy Efficiency, 2013. -Tajikistan tax incentives for renewable energy, 2013 -Tajikistan Energy Saving and Energy Efficiency Law, 2013. -Sustainable Energy for All Tajikistan 2013-2030, 2013. -Programme for Efficient Use of Hydropower Resources and Energy 2012-2016, 2011. -Tajikistan Law on Use of Renewable Energy Sources (Law No 587) (Renewable Energy Law of Tajikistan). -Special Program for Renewable Energy Sources Use in Tajikistan (2007-2015).	-National Strategy of Turkmenistan on Climate Change 2019. -Law on protection of the atmospheric air, 2016. -The Law of Turkmenistan on Electricity (2014). -Law on Environmental Information. -Energy Saving Program for 2018-2024. -Law on hydrocarbon resources, 2008.

Threats presented by renewable energy to Central Asian economies dependent on fossil and hydropower

Only a decade ago in 2010, the price of oil and gas seemed to remain high and even increase in the foreseeable future. It all changed in a span of several years. First, fracking technology developed by American producers disrupted the pricing in global markets since 2012 with an extra supply of shale gas (BP 2013). Then, several countries increased oil and liquefied natural gas (LNG) output, while Iran returned to the market as a major exporter. Outside of changes in global supply and demand, the American shale revolution is not the only

technological development disrupting the energy markets. The biggest disruptor coming yet for hydrocarbon consumption is renewable technology rapidly replacing fossils with unprecedented declines in the competitiveness of traditional energy sources (IRENA 2020). As a result, tumbling hydrocarbon revenues threaten the very economic models of development of the countries that appeared sound only a few years ago (Cohen 2020). Hydrocarbon exporters in Central Asia should take steps for adapting national economies to the global changes happening in the energy sectors of major importing countries. Exports of coal and oil are likely to drop worldwide in the coming decades. Though consumption of Central Asian gas is not likely to decrease in main import markets, its price would probably never get back to the high levels that were the norm in the recent past.

Policymakers in Central Asia cannot be complacent with abundant hydrocarbon and hydropower resources providing cheap energy at the current levels. First, fossil fuel will be depleted sooner or later, so the expensive long-term infrastructure for renewable energy should be developed in advance. Second, with the current pace of development, wind and solar power could well become cheaper than fossil or hydropower with the lowest cost. The dependency of Kazakhstan, Uzbekistan, and Turkmenistan on hydrocarbon exports for state revenues and fossil fuel for electricity will become increasingly problematic. Warnings to countries excessively relying on exports of hydrocarbon resources have long been made, but it is an enormous challenge to wean off of oil and gas in the growth of the economies (Cohen 2020). Main import markets in Europe and China would still need coal, oil, and gas in their energy mix in any scenario as the transition to 100% renewables is hardly attainable in liberalized markets: a consequence of the so-called "energy paradox" when increasing renewables share requires co-existence with fossil (Blazquez et al 2018). Moreover, the share of gas in energy consumption in the key Chinese market is non-decreasing under realistic scenarios. The share of oil and coal as a particularly heavy polluting fossil in the global energy mix will continue to decline. The main issue for fossil fuel exporters is not volume but value. State budgets of commodity exporters will suffer from prices expected to be lower than planned after post-pandemic shocks, increasing efficiency, greater supply, and of course disrupting technology such as renewables. Furthermore, the decline in fossil fuel prices can have negative effects on the socio-political stability of countries that excessively rely on hydrocarbon resources (de Jong 2017).

State planners in Uzbekistan, Kazakhstan, and Turkmenistan should thoroughly review the structure of economies and export strategies as renewables increase their global share. This must include a continuous review of costs and risks of planned pipeline projects for delivering hydrocarbon to countries that already managed to reach the most competitive renewable generation such as India, China, and an increasing number of European countries. Countries that previously declared willingness to import more fossil fuel could soon revise their plans as cheap renewables become abundant internally and more suppliers become available externally. Measures that were taken to diversify exports in all the mentioned Central Asian countries so far appear to demonstrate limited or moderate performance or their impact is yet to be seen in the future. Renewables thus should become part of the solution in efforts for diversification and shift to a knowledge economy. Massive costs directed towards fossil subsidies and investments should be reconsidered in favor of renewables.

The impact of renewables is not limited to the aforementioned three countries in the region that depend on hydrocarbon resources. Tajikistan and the Kyrgyz Republic should rethink the role of hydropower in electricity exports and supply for national economies. The perspective for the expansion of environmentally-friendly hydro energy is vast in both countries. While the generation of cheap electricity using current hydropower plants would remain economically effective, governments of the two Central Asian countries rich in hydro resources should exercise caution about future expansion and modernization plans. With the current pace, a wider introduction of cheap wind and solar energy is expected to become a viable alternative to additions to the existing hydropower facilities in the energy mix. If policy-makers in those countries also consider geopolitical and environmental factors, the expediency of choosing wind or sun instead of excessive hydro capacity becomes all more evident. Planning and building massive hydropower plants requires a great amount of time and resources that even larger countries find difficult to afford. This means inherently higher risks of investments in hydro energy. For instance, the construction of the Rogun Dam in Tajikistan was planned already in the Soviet era. This project involved controversy and transboundary tensions leading to a lack of funding from major institutional investors, which in turn increased the already high dependency of the country on Chinese investments. The Naryn cascade project in the Kyrgyz Republic involving small hydropower plants had a similar history of controversy involving Russian and Czech investors and tensions with neighbors. Though irrigational benefits (not considered in this report) always play role in

corresponding decision-making, energy supply and exports of hydropower in any planned expansion of related capacity looks increasingly questionable.

Governments in Central Asia to various extent favored grand projects with heavy public spending in major sectors of national economies that showcase development to a local and international audience. This could concerns investments in renewables too (Nabiyeva 2018). Meanwhile, the creation of a modern competitive economy requires a shift from the elements of centralized government planning to a decentralized structure that favors the private sector with strong small to medium enterprises. The development of distributed PV and small-scale onshore wind should be mentioned separately here. Until recently, most power plants all around the world required investments in projects of medium to large scale with the unavoidable involvement of the public sector. Rooftop and other PV together with onshore wind allows smaller businesses and even households to benefit from their relatively cheap costs and contribute to the national energy mix. With enough beneficiaries and support, an advanced level of virtual power plants using digital technologies to control energy demand, storage and distributed generation can be achieved. Advanced transport, heating, and cooling systems should not be neglected as a growing area of renewables.

An example of the EU response to the coronavirus pandemic appears highly relevant for Central Asia. European funding will increasingly support sustainable development where renewables play a major role. The timing seems right in this respect for Central Asia too now that power infrastructure in the region needs modernization. Instead of grand government projects with risky financing terms that favor plants based on fossil, the focus should shift to smaller wind and solar plants based on private or mixed ownership that is located in underdeveloped areas. As much as possible, such projects should involve global institutional investors that are reputable for applying rigorous practices considering the socio-economic and sustainability interests of local and neighboring populations. EBRD, ADB, UNDP, USAID, GIZ, JAICA, World Bank, and similar organizations and institutions already present in the region could all play an active role. In addition, Central Asian countries should more actively involve technical assistance and conduct evaluation from international organizations specializing in renewables such as IRENA and REN21. This strategy would make the respective economies less exposed to volatile exports of commodities after the pandemic outbreak while simultaneously helping solve economic and environmental problems associated with fossil and hydropower in the long-term.

Summary

Long-term development plans of Central Asian countries did not and, in fact, could not sufficiently take into account the impact of wind and solar renewables that few countries could envision several years ago. Countries of the region already seem to be late in adapting to the ongoing green energy revolution. Given the decreasing cost trend of renewables and the long-term nature of investments in power plants, governments of the region could be missing opportunities for the creation of a more sustainable energy mix because the current plans to expand fossil power likely underestimates the region's vast potential for renewable energy. Policy-makers increasingly incorporate renewables into strategies for further national development after the pandemic outbreak and slump in commodity markets. The role of foreign partners could be crucial for the development of renewables in Central Asia. Global institutional investors could work closely with private and public sectors in the region to ensure high standards of transparency and sustainability for stakeholders. In particular, governments and international organizations could be highly selective when approving the form of renewables to invest in. Taken as a region, Central Asia has a higher potential for onshore wind and sun compared to other parts of Eurasia. Distributed low-cost PV that benefits individual consumers and small businesses in rural and other underprivileged areas with poor infrastructure seem to be a suitable case. At the same time, legal and other supporting reforms should be encouraged and considered in international agreements to support vulnerable populations and other target beneficiaries with policies such as feed-in tariffs.

In view of the low availability of country-specific data on renewables in Central Asia, more research would be needed to gain deeper insight on the subject. Statistical and other agencies in the region should work on gathering and disclosing more information on renewables so the policy-makers and investors could make more informed decisions on how best to contribute to development in the sector. Future work should also involve precise research on actual costs and reasons for low development levels of non-hydro renewables in the region.

References

Ajadi, T., Cuming, V., Boyle, R., Strahan, D., Kimmel, M., Logan, M., & McCrone, A. (2020). *Global Trends in Renewable Energy Investment 2020.* Frankfurt School-UNEP Centre/BNEF.

Bellini (2020) Uzbekistan Pitches for 5 GW of Solar by 2030. *pv magazine.*

Blazquez, J., Fuentes-Bracamontes, R., Bollino, C. A., & Nezamuddin, N. (2018). The Renewable Energy Policy Paradox. *Renewable and Sustainable Energy Reviews*, 82, 1-5.

BP (2013) *Statistical Review of World Energy 2013.*

Chachine (2019) *Sustainable Energy For All in Eastern Europe, the Caucasus and Central Asia. Analysis of National Case Studies.* UNECE.

Cohen, A. (2020) Central Asia Needs a Financing Solution to Low Oil Prices. *Forbes*.

Daley, J. (2019) Putting Solar Panels on Water Is a Great Idea — but Will It Float? *Scientific American.*

Darby, M., Gerretsen, I. (2019) *Which Countries Have a Net Zero Carbon Goal?* Climate Home News.

de Jong, S., Auping, W. L., Oosterveld, W. T., Usanov, A., Abdalla, M., Van de Bovenkamp, A., & della Frattina, C. F. (2017). *The Geopolitical Impact of Climate Mitigation Policies: How Hydrocarbon Exporting Rentier States and Developing Nations Can Prepare For a More Sustainable Future.* The Hague Centre for Strategic Studies.

EBRD (2018) *The EBRD in Central Asia.*

EIU (2017) *Central Asia Falling Short of Power Generation Potential.* The Economist Intelligence Unit.

Enerdata (2020) *Uzbekistan Energy Report.* https://estore.enerdata.net/energy-market/uzbekistan-energy-report-and-data.html

Energydata.info (2020) *Global Wind Atlas.*

Energypedia (2020) *Tajikistan Energy Situation.* energypedia.info

European Commission (2020) *2050 Long-Term Strategy*. https://ec.europa.eu/clima/policies/strategies/2050_en

Gassner, K. B., Rosenthal, N., Hankinson, D. J. (2017). *Analysis of the Kyrgyz Republic's Energy Sector.* The World Bank.

GlobalPetrolPrices.com (2020) *Electricity Prices Around the World.* https://www.globalpetrolprices.com/electricity_prices/ (accessed on 20.09.2020).

Hamawand, I., Sandell, G., Pittaway, P., Chakrabarty, S., Yusaf, T., Chen, G., Hopf, J. (2016). Bioenergy from Cotton Industry Wastes: a Review and Potential. *Renewable and Sustainable Energy Reviews*, 66, 435-448.

He, G., Lin, J., Sifuentes, F., Liu, X., Abhyankar, N., & Phadke, A. (2020). Rapid Cost Decrease of Renewables and Storage Accelerates the Decarbonization of China's Power System. *Nature communications*, 11(1), 1-9.

Hodgins, G. (2020) *What is Floating Solar?* Float Pac.

IEA (2020) *Countries and Regions.* https://www.iea.org/countries (accessed on 20.09.2020).

IRENA (2019) *Renewables Readiness Assessment - Republic of Azerbaijan.*

IRENA (2020) *Renewable Power Generation Costs In 2019.*

Kolodin, M.V, Chariev, H. (1996) Testing Results of a Combined Solar-Wind Power System (KGVES) in the Karakum Desert *Desert Exploration Problems.*

Marques, J., G. (2018) *Renewables in Central Asia.* The Business Year.

Nabiyeva, K. (2020) The Weekend Read: Central Asia's Green Horizons. *pv magazine.*

Normile, D. (2020) Can China, the World's Biggest Coal Consumer, Become Carbon Neutral by 2060? *Science*.

NS Energy (2020) *Central Asia-South Asia (CASA-1000) Electricity Transmission Project*. https://www.nsenergybusiness.com/projects/casa-1000-electricity-transmission/

Vallely, P. (2017) *Promoting Regional Electricity Trade in Central Asia.* World Bank Group.

Redman, J. (2020) 3 Cents per kWh – Central Asia's Cheap Electricity Entices Chinese Bitcoin Miners. *Bitcoin News*. https://news.bitcoin.com/central-asias-cheap-electricity-chinese-bitcoin-miners/ (accessed on 20.09.2020).

REN21 Secretariat (2020). *Renewables 2020 Global Status Report.*

Solargis (2020) *Solar Resource Map.* World Bank Group.

The Economist (2020) *America's Domination of Oil and Gas Will Not Cow China.*

The World Bank (2020) *Uzbekistan – Navoi Scaling Solar Independent Power Producer Project* https://www.worldbank.org/en/news/loans-credits/2020/09/22/uzbekistan-navoi-scaling-solar-independent-power-producer-project

UNDP (2020) *Mid-term evaluation of the project "Energy Efficiency and Renewable Energy for Sustainable Water Management in Turkmenistan".*

https://erc.undp.org/evaluation/managementresponses/detail/9411 (accessed on 20.09.2020).

United Nations in Turkmenistan (2020) *Sustainable Cities - Territory of the Future.* https://turkmenistan.un.org/en/98555-sustainable-cities-territory-future

UNESCO (2015) *Science Report: towards 2030.* Paris.

Xinhua (2019) *AIIB to fund Central Asia's Largest Wind Power Plant in Kazakhstan.* http://www.xinhuanet.com/english/2019-12/16/c_138635850.htm