Barriers to renewable energy transition in a developing oil-exporting country: The case of Kazakhstan

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Abstract

This study aims to investigate the barriers hindering the transition to renewable energy sources (RES) in Kazakhstan, a developing oil-exporting country facing rising energy demand, environmental degradation, and increasing pressure to meet international climate commitments. The research combines a review of relevant literature with insights drawn from 20 structured expert interviews, applying the analytical framework developed by J. P. Painuly. The research then provides a comprehensive analysis of the barriers to RES adoption in Kazakhstan and their implications for policy and investment. This analysis is structured around seven key barrier categories: (1) market failures and imperfections; (2) market distortions; (3) economic and financial; (4) institutional; (5) technical; (6) social, cultural, and environmental and (7) other barriers. The findings indicate that while Kazakhstan possesses significant renewable energy potential, its realization is obstructed by several challenges, which include among others high risks associated with renewable energy projects, the lack of competitiveness of renewables due to government subsidies for conventional energy, barriers faced by small producers and prosumers, the need for regulatory improvements and increasing public awareness. Despite some positive policy developments, such as revised power purchase agreements, substantial reforms are still needed to improve market access, mitigate investment risks, and enhance institutional capacity. This paper contributes to the broader discourse on energy transitions in oil-dependent economies and offers policy-relevant insights to support the country's shift toward a sustainable and diversified energy future.

Keywords: renewable energy sources; oil-exporting countries; energy transition; barriers to renewable energy transition; Kazakhstan

1. Introduction

The world is shifting from fossil fuel energy to renewable energy sources (RES). This process is not without challenges, but the general direction is evident. The shift to renewables is particularly

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difficult for many developing oil-exporting countries (OECs). This is because the governments of these countries often support their populations through fuel subsidies, tax rebates, and other measures funded by oil revenues. At the same time, this dependence on oil revenues has become a barrier to the adoption of RES. Certainly, other factors also play a role and are addressed in this article. Nevertheless, "oil-exporting countries cannot afford to ignore the transition of the energy sector, which can disrupt their business model and erode their revenue base. For this, they need to understand what aspects of energy transition affect their business activities" [1].

In any case, the oil era is coming to a definite end, which will largely lead to the discontinuation of oil revenues in these countries. Therefore, the shift to RES is unavoidable. This paper attempts to study the barriers to the penetration of RES and their implications in Kazakhstan, which is a typical oil-exporting country. A review of the relevant literature and structured interviews were utilized as the primary research methods.

2. Kazakhstan: Geography, Economy and Efforts Towards Transition to RES

Kazakhstan, a former Soviet republic in Central Asia, is the world's largest landlocked country, covering 2.7 million square kilometres, making it the ninth largest country in the world. Astana is the capital, and Almaty (the former capital) is the largest city. The distance between the most distant points of the country is 2,930 km from East to West and 1,652 km from North to South. This vast territory allows Kazakhstan to possess significant renewable energy potential.

Deserts and semi-deserts occupy 44% and 14% of Kazakhstan's territory, respectively [2]. This means that a major part of the country's territory is not utilized for agricultural purposes and can be easily converted into solar or wind farms, diminishing the importance of siting RES facilities. This decreases the capital costs of RES projects. From geographical and meteorological points of view, there is tremendous potential in utilizing more wind power, solar installations, and biomass to increase the renewable share in the country.

Corruption remains a serious problem. Kazakhstan ranks 93rd out of 180 countries on the Corruption Perceptions Index, with a score of 39. However, its ranking has steadily improved since 2013 and is the least corrupt among its neighbors, excluding China [3].

In 2023, the country's population exceeded 20 million, and it is growing rapidly. Its density is very low, one of the lowest in the world [4]. Low population density imposes its own requirements and limitations on the needs of consumers and the electrical grid infrastructure. For example, the use of RES is often the best decision for the energy supply of small and remote settlements where grid-provided electricity is either not available or unreliable.

Extractive industries – the production of oil and gas, ferrous and non-ferrous metals, uranium, and coal – are the backbone of the Kazakh economy. According to [5], this country was the 11th biggest oil exporter in 2023. It holds the 9th place in the world in proven oil reserves, most of which are located in the western regions. It is heavily dependent on oil revenues, and this dependence has a negative impact on economic and social stability, as well as environmental sustainability. In addition, the country's uranium and coal deposits are the second and eighth largest in the world, respectively [2]. The abundance of various natural resources is combined with well-developed oil refining, ferrous and non-ferrous metallurgy, chemical, food, and other industries, as well as agriculture. With regard to power generation, [6] notes that its structure in Kazakhstan "is dominated by coal generation". As [7] reports, serious regional discrepancies exist because "around 80 per cent of electricity is produced in the country's north, where the coal mines are located."

The RES potential of Kazakhstan is huge and far exceeds that of the neighboring Central Asian countries. The country also leaves its Central Asian neighbors well behind in terms of RES deployment [8]. Despite Kazakhstan's relative economic success, progress in shifting to renewable energy remains insufficient. The country's Energy Transition Index rank is just 98th out of 120 [9], with the energy sector responsible for approximately 75% of all greenhouse gas emissions [10]. The share of electricity produced by renewable energy sources (mostly wind and solar) has been growing but remains low. As [11] reports, this share (excluding large hydroelectric power plants) has grown from 0.6% in 2015 to 5.82% in 2023. In addition to clear environmental benefits, the shift to RES offers multiple long-term economic benefits; e.g., it encourages economic diversification, making the Kazakh economy more competitive. As reported in [11], final energy consumption in the country has been growing. Combined with the fact that Kazakhstan is a net importer of electricity, there is an opportunity for RES to at least partially decrease this dependence. Also, ensuring a stable electricity supply for off-grid areas offers clear social benefits.

The objectives of this research are to analyze the barriers that have impacted the shift to RES in Kazakhstan and to define their potential implications for policy and investment.

3. Literature Review

The body of literature on the transition to renewables in developing OECs is smaller than that on this transition in developed countries. The amount of research focused on Kazakhstan is even more limited. This article attempts to partially fill this gap.

3.1. Challenges in transitioning to renewable energy in OECs

First attempts to address this issue date back decades, e.g., [12]. Certainly, there were later attempts to examine this phenomenon. In [13], this shift was called "a threat to resource economies". [14] "discusses ... a transition of a resource-rich country to a green economy and a sustainable energy future." Analyzing barriers to the transition to RES in Kazakhstan, [15] identified the most significant barriers to the uptake of renewable energy. An interesting observation was made in [16]: "Oil provided a guaranty to everyone that there will always be jobs, pensions, decent roads, and schools. Oil provided all that, and it also allowed entrepreneurs to do business; this is how private business grew." Such opinions are quite widespread and play their role in slowing down the shift to renewables. Discussing "Gulf Cooperation Council (GCC) countries," [17] argues that "their decision-makers are fearful of transitioning from conventional energy sources to clean renewable energy, since the latter typically calls for huge investments [that] they are not ready for." [18] explored "the main challenges that impacted the move to a more circular economy in oil-exporting countries during the COVID-19 pandemic, addressed the reasons for these challenges, and suggested ways to respond to them." Admitting that "achieving energy transitions is challenging to all," [19] advises that "this challenge is even greater for oil-exporting countries".

3.2. Energy subsidies in the OECs

Energy subsidies were discussed in several literature sources, including [20], which pointed out: "The collapse in oil prices provided impetus for reforms, particularly of energy subsidies. In countries where such reforms were undertaken, energy subsidies represented nearly 6 percent of GDP before the 2014-16 oil price collapse. Between mid-2014 and the end of 2016, a majority of oil-exporting EMDEs (emerging markets and developing economies) introduced subsidy

reforms, although in various forms and to varying degrees across countries." They still exist in Kazakhstan [21]. The Government of the country "adheres to a policy of containing tariffs and prices for energy resources (through energy subsidies), pursuing social and political goals" [22]. The same source mentions that "the amount of government funding for fossil fuels is several times higher than spending on government programs aimed at improving energy efficiency and reducing greenhouse gas (GHG) emissions directly or indirectly." Unfortunately, the amount of these subsidies has been growing over recent years [23]. Concluding this topic, it is worthwhile to refer to [24], which points out that "it cannot be overemphasized that market distortions, particularly tariff subsidies, must first be rationalized".

3.3. Government efforts to promote energy transition in Kazakhstan

The Kazakh government has adopted several policies, legal, and regulatory documents, including the Strategy Kazakhstan 2050, which, among other things, states that "by 2050, alternative and renewable energy sources must provide for at least half of the country's total energy consumption" [25], the Concept for Transition of the Republic of Kazakhstan to a Green Economy until 2050 [26], Kazakhstan's Vision to Achieve Carbon Neutrality by 2060 [27], the Carbon Neutrality Strategy Until 2060 [28], the Law on Support of the Use of Renewable Energy Sources [29], the Ecological Code of the Republic of Kazakhstan [30], etc. The government has declared that switching to RES is one of its priorities [31]. As one can see, the country's government has officially and repeatedly declared its commitment to and support for the energy transition. At the same time, "Despite the different orientation, all the works of Kazakhstani researchers agree that the legislative (regulatory) framework adopted in Kazakhstan is imperfect and that the state of RE development lags behind the strategic goals" [32]. The government introduced a series of concrete measures aimed at promoting RES in the country including "the possibility of selling the produced electricity from RES to the public grid at special rates through the Settlement and Financial Center for Support of RES, which guarantees the purchase of electricity from RES. These producers are exempt from paying for the services of energy transmission organizations for the transmission of electricity, and priority is given to RES when transmitting electricity through grids" [33]. However, the same source reports, "to obtain the above-mentioned support measures, the implementation of renewable energy projects is carried out through the auction mechanism". We will address this further below.

3.4. Potential of renewable energy sources in the country

[34] informs that "Kazakhstan is one of the richest countries in the world in terms of renewable resources, evaluated at over 1000 billion kWh/year." "Modern renewable energy sources (RES) have significant potential for improving energy security at the global, national, and local levels" [35]. In addition to the scientific works mentioned in the Introduction, there are other scientific publications that have studied this topic. Among them, there is [24], which draws attention to the fact that, "Kazakhstan has large reserves of conventional resources, but these are largely undeveloped and would require extensive network development or upgrading to be able to service what is a very large territory," and [7], which points out, "the highly favorable landscape for renewable energy development." Other attempts to holistically review the future potential of renewables in Kazakhstan were made in [36], [37], and [38]. [15] provides a review of Kazakhstan's energy resource potential from both non-renewable and renewable energy sources. [39] investigated the efficiency of green energy projects in the country. [40] studied "the share of renewable energy in energy production as well as the use of solar energy for electricity generation". [14] "discusses the

challenges and prospects of wind power...".

3.5. Barriers preventing wide-spread use of renewables in Kazakhstan

Publications that address this topic include [41], which discusses the "lack of incentive for both government officials and investors to launch renewable energy facilities." The same source pays particular attention to corruption, noting that "issues of corruption and its perception remain problematic for the attractiveness of capital investment... indicators still remain below what may be necessary to attract the requisite FDI for energy transitions." Among others, our attention was attracted to [36], where "the barriers to the adoption of renewables are analyzed within the context of national climate and energy goals". The same source provides recommendations "for the promotion, development, and implementation of renewable energy resources". [6] assessed the biomass-based green hydrogen production potential. Other similar publications include [32], which analyzed challenges and prospects for RES development in Kazakhstan; [35], which "revealed the main barriers and factors that favorably affect the growth of venture investments in alternative energy"; and several others. A comprehensive review of the challenges facing RES and their impact on industry growth is presented in [42]. The following sections examine their findings in more detail.

3.6. Barriers preventing transition to renewables in developed countries

In examining the transition to renewables in a developing, oil-exporting context like Kazakhstan, it is crucial to review the experience of developed countries. Research in this area is extensive: studies have addressed overcoming barriers and uncertainties in residential solar PV adoption in the USA [43], discussed similar issues in relation to Hong Kong [44] and [45] and considered social, economic, technological, and regulatory barriers across the Baltic states (Estonia, Latvia and Lithuania) [46]. A key observation, arising from the experience of the German energy transition (Energiewende) [47], is that "Out of multiple technologies wind and solar power... turned out to be cheaper than the use of oil, coal, gas or nuclear energy for power generation, even without considering externalities". Furthermore, a review of Finland and Poland [48] identified unflexible, ineffective, and excessive regulatory frameworks; limited financing options; and an insufficient level of societal awareness as the main bottlenecks for the diffusion of renewable energy technologies.

3.7. China's Belt and Road Initiative and its impact on transition to renewables

As an Asian country involved in the global energy transition, Kazakhstan's experience should be contextualized within the influence of China's Belt and Road Initiative (BRI). The BRI was first announced in Kazakhstan in 2013, highlighting the country's strategic significance. Recognizing the initiative's environmental challenges, the Chinese government later proposed the "Green Belt and Road Initiative" [49]. Earlier publications also addressed the environmental aspects of the BRI [50], and subsequent analyses confirmed that "the BRI project indeed improved the renewable energy development in host countries" [51]. Furthermore, the relationship between the BRI and transnational environmental governance has been examined, drawing "attention to the contributions of private actors in realizing the vision of the Green Belt and Road Initiative" [49,52].

4. Materials And Methods

A qualitative approach was chosen as the most suitable method for achieving our research objectives. Our study utilized a literature review and structured interviews as its research methods and involved the following steps: (i) Reviewing relevant literature; (ii) Preparing for and conducting structured interviews; (iii) Transcribing, verifying, and cross-checking responses; (iv) Processing and analyzing the collected data; and (v) Summarizing findings and drawing conclusions.

4.1. Structured interviews

We adopted the analytical framework developed in [53] for collecting information on potential barriers that hinder the development of RES in the country. This framework categorizes major barriers; however, as the source notes, the classification is not rigid: "The classification of barriers in a category is not very rigid. Some barriers can belong to more than one category, and in some cases, readers may want to assign a barrier to a different category than the one assigned here. Some barriers may also be related to each other, or in some cases may have a cause–effect relationship even within a level". Using this framework ensures consistency in data collection. A similar approach to identifying barriers to renewable energy adoption in Kazakhstan was also employed in [15].

Interviewees were selected based on their knowledge of the topic and relevant work experience. Please note that the words "interviewee", "respondent" and "informant" are used interchangeably throughout this text. They were either currently employed or had previously worked in government agencies, private and public companies, international and non-governmental organizations, or academia during the 2023–2024 period when the interviews were conducted. Their profiles are provided in Table 1.

Every effort was made to ensure professional and geographic diversity among interviewees, with the primary goal of obtaining unbiased, comprehensive insights and examining the research objectives from multiple perspectives. The number of interviewees was inherently limited by the nature of the study. Initially, 45 individuals were approached, with careful pre-screening of potential respondents. Of these, 25 either declined to participate or lacked sufficient knowledge of the subject matter. Ultimately, 20 individuals with relevant expertise were interviewed. The interviews were conducted both in person and online via Teams, Zoom, or WhatsApp. A group of students from the Kazakh-British Technical University assisted in the process.

4.2. Ensuring validity and reliability

Despite the small sample size, we reached data saturation. Sufficient data were collected to draw meaningful conclusions, and additional interviews did not yield any new insights. The information obtained through interviews was complemented by a review of numerous literature sources, allowing for triangulation. The same approach was used in [41]. In addition, we attempted to cross-check answers where possible. Numerous follow-up calls were made to clarify and verify answers. We also recontacted individuals interviewed in 2023 and early 2024, requesting that they reconfirm or update their previously expressed opinions.

4.3. Research ethics

Due attention was paid to the research ethics issues, particularly those relevant to government policies and actions, as they could be considered sensitive. This is why some informants insisted

Table 1: *Profiles of Interviewees*

#	Occupation or Position	Company	Location	Comments
1	SDG and ESG expert	Non-governmental organization	Almaty	Has strong reputation among RES professionals
2	Associate Professor	Suleyman Demirel University	Almaty	Regularly publishes on RES issues
3	Former high-level official	Ministry of Environment	Astana	Was responsible for RES development
4	Former high-level official	Ministry of Energy	Astana	Was responsible for RES development
5	Top manager	Regional Investment Company	Atyrau	A public company
6	Entrepreneur	Private engineering company	Karaganda	Implemented a wind farm construction project
7	Investment Officer	International development bank	Astana	Works for a representative office in Kazakhstan
8	Entrepreneur	Private engineering company	Taraz	Implemented a solar farm construction project
9	Senior manager	Samruk-Kazyna	Astana	Public company, a Kazakh sovereign wealth fund
10	Mid-level official	Regional administration	Kokshetau	Responsible for RES projects development
11	RES Expert	Non-governmental organization	Almaty	Participated in several RES projects
12	Engineer	Private oil company	Aktau	Responsible for installing and servicing solar panels
13	Manager	Foreign renewable power company	Astana	Works for a representative office in Kazakhstan
14	Scientist	Research institution	Almaty	Studies RES in Kazakhstan
15	Engineer	Foreign engineering company	Shymkent	Participated in several RES projects
16	Consultant	Foreign consulting company	Almaty	Assisted in the development of several state programs on RES
17	Entrepreneur	Private engineering company	Ust-Kamenogorsk	Worked on a small hydro-power project
18	Engineer	Private engineering company	Ust-Kamenogorsk	Worked on a small hydro-power project
19	Officer	International development agency	Astana	Assisted in the RES projects development
20	Engineer	Foreign energy company	Taraz	Participated in several RES projects

that their identities remain confidential. They contemplated that their answers could prove sensitive for their current or previous employers, or for their future careers. This issue is also discussed in the research limitations section below. We assured respondents that their answers would remain anonymous, as reflected in Table 1.

5. Results and Discussion

We closely adhered to the framework outlined in [53], which categorizes the major barriers hindering Kazakhstan's transition to RES. Our findings are presented below.

5.1. Market failure

We paid particular attention to the highly controlled energy sector barrier. Our interviewees identified it as a significant obstacle for small producers in remote areas, where low purchasing power limits access to essential equipment. Many residents cannot afford to invest in the necessary infrastructure and are forced to buy electricity illegally from wealthier neighbors because the legal process requires producers to sell electricity to the grid first. However, grid reliability in these areas is often poor, with frequent interruptions. Simplifying government regulations for small producers, consumers, and prosumers is essential to addressing this issue. The informants also cited the case of a prosumer who encountered numerous challenges when attempting to sell electricity to the grid. [54]. For larger producers, the situation is different, as their investment

programs are developed and implemented in coordination with the Ministry of Energy, which is under pressure to increase the share of renewables.

Lack of information and awareness barrier: According to the opinions of our interviewees, RES and their utilization remain a largely misunderstood concept. Many people in Kazakhstan and other oil-rich countries still believe that switching to renewables makes little sense for these countries. Their primary concern is that it will result in higher electricity tariffs. These individuals have limited (if any) knowledge about the global energy transition and its inevitability. Interestingly, they tend to change their perspective quickly after receiving more information.

The High investment requirements barrier was highlighted by most of our informants. This barrier results in elevated required returns for RES projects. As a result, such projects are seen as more expensive than those using conventional energy sources, and many potential investors consider them risky.

Our informants did not view other barriers in this category as particularly serious, except for certain elements of the Poor market infrastructure barrier, specifically the lack of liberalization in the energy sector and the mismanaged energy sector. However, the lack of liberalization in the energy sector has already been addressed under a highly controlled energy sector, while the discussion of energy sector mismanagement has generated complaints about the general management of the energy sector caused by the absence of qualified specialists. We cover this further below when we describe the Institutional category and the Lack of infrastructure barrier.

5.2. Market distortions

Favorable treatment for conventional energy: as extensively discussed in the Literature Review section, energy subsidies in the OECs create a significant barrier to renewable energy adoption. The higher cost of energy from renewables cannot be an advantage against the backdrop of low electricity tariffs. However, it is government policy to keep energy tariffs low. In pursuit of this objective, the government also subsidizes non-renewable energy, and these subsidies significantly surpass the assistance allocated for renewable energy. Some of our informants argued that this policy needs to be revised. Others, while acknowledging the necessity of such a change, emphasized that it could trigger public discontent if not preceded by a general increase in the purchasing power of the Kazakh population. They pointed to the January 2022 mass protests, which were sparked by a sudden rise in LPG fuel prices after the government lifted subsidies on New Year's Day. In response to the unrest, the government was forced to reinstate these subsidies.

Respondents also noted that the cost of conventional energy fails to account for externalities, such as air pollution, which has become a serious issue in many large cities. However, they considered this a separate and complex challenge requiring dedicated attention from both the government and the public. According to our respondents, other barriers in this category have a minimal impact on the transition to RES.

5.3. Economic and financial

Barriers in this category are closely connected with the High investment requirements barrier mentioned earlier. These barriers create a situation where investors in RES projects are generally from the energy sector, while the financing of RES projects is predominantly provided by development banks [42]. The same source continues that "renewable energy investments are particularly relevant in the oil-gas and energy sectors to ensure compliance with legal requirements on greenhouse gas emissions (and to avoid paying penalties), as well as to sustain the company's market value". These statements (about investors and financiers) were reconfirmed by our interviewees.

They also reconfirmed the information given in the Introduction that, in many cases, off-grid applications for RES appear to be less expensive and more reliable in comparison with traditional energy supply schemes, namely in small and remote settlements.

Our private sector respondents acknowledged that there is strong competition for skilled labor from the oil and gas industry. In many cases, experienced professionals prefer to work for oil companies, where they can earn higher salaries for the same workload. Regarding other barriers in this category, our respondents noted that financing extended to small and medium-sized businesses is practically prohibitive. For example, local banks often charge annual interest rates exceeding 35%, with loan terms of less than five years. Another serious issue is the general reluctance of local banks to finance RES projects, as discussed earlier.

5.4. Institutional

Our informants repeatedly stated that government institutions do not effectively facilitate or support the development of renewables in the country, despite numerous official declarations and international commitments, as mentioned in Section 2.3. [42] further addresses "the role of the state in reducing investment risks. To make RES projects more attractive for private investors and financial institutions in Kazakhstan, the Government should ensure the solvency of RES producers and amend offtake agreements to match international standards." Also, according to several informants, it would be inaccurate to say that the government provides no support, as some support does exist. However, significantly more is needed to effectively implement the government programs outlined in the Literature Review section. They specifically emphasized that the legal framework, and especially the regulatory framework, requires substantial improvements. As one of our respondents explained: "The conventional sources of energy are in a privileged position. They have practically all the legal and regulatory documentation required. This is not the case for RES. Some of the documents needed are missing. The others must be amended. Usually, no one's malice is behind this situation. We are simply at the beginning of the process." This person then provided examples of the practical absence of an established system of carbon emissions trading or regulations to support microgeneration. His opinion can be expanded based on the literature sources. For instance, it is stated in [24] that it is essential to "establish a proper legal and institutional framework in which the various players can perform their respective roles with confidence and effectiveness". This issue is closely linked to the previous point, as adequate government support could help improve the situation. Some positive developments have already been made. For example, in December 2023, the Kazakh government introduced amendments to the standard power purchase agreement for energy-producing organizations utilizing renewable energy sources. Our informants viewed these amendments positively.

However, several respondents expressed concerns that navigating the auction mechanism is extremely challenging, if not impossible, for small producers. Since participation in the auction is required to access government support for RES projects, as outlined in Section 2.3, this poses a significant barrier to their implementation. Furthermore, the unstable macroeconomic environment was frequently cited as a major barrier, with respondents agreeing that it discourages investment from both RES project sponsors and external investors.

Our interviewees believe that the lack of private sector participation is primarily a consequence of other barriers, mostly from the Economic and Financial category. They did not consider other barriers in the Institutional category to be significant.

5.5. Technical

Among the barriers in this category, the lack of skilled personnel was most frequently highlighted by our informants. They repeatedly emphasized its significance, noting that it does not receive proper attention from the relevant government bodies. In any case, the barrier is typical for the energy sector worldwide. [55] confirms this warning that "the global power industry faces a 3.9 million workforce gap, exacerbated by a skills gap amid increasing competition for skilled employees". Kazakhstan's vast territory and small population also contribute to the shortage of qualified specialists. Respondents particularly emphasized the lack of technicians with high-voltage work permits. They expect the government to improve the vocational and technical training system, which has significantly deteriorated in recent years.

This barrier is closely linked to the lack of O&M (operation and maintenance) facilities. Most RES facilities in Kazakhstan are relatively new and currently require minimal maintenance or repairs. However, as equipment ages, the demand for preventive maintenance, repairs, and skilled personnel will continually increase.

Entrepreneurs' barriers, driven by relatively low profitability and restrictive regulations, have sparked several interesting discussions. Two informants acknowledged this challenge, admitting that they had initially decided against implementing such projects due to these concerns. However, they later regretted their decision when they saw similar projects being successfully carried out by others.

Other constraints are primarily related to the nature of RES, including their intermittent power supply and the temporary lack of adequate energy storage systems in the country. Water pumping, a widely used energy storage method, faces significant limitations in Kazakhstan due to low winter temperatures. Our respondents did not consider other barriers in this category to be significant.

5.6. Social, cultural and behavioral

We did not identify significant issues with consumer or social acceptance. While some reluctance exists due to a lack of awareness, this can be addressed through targeted information campaigns, as discussed in Section 4.1: Market Failure.

5.7. Other barriers

Most barriers in this category have already been addressed. However, we offer additional comments. First, while environmental issues are expected to become more pressing in the future, proactive decisions must be made now regarding the disposal of solar panels at the end of their lifespan. If not properly managed, they could pose a toxic waste hazard. Therefore, the country must develop effective recycling and reuse strategies. Second, our respondents agreed that the country's electrical grid, mostly built during the Soviet period, is becoming increasingly outdated. They identified this aging infrastructure as one of the country's most significant challenges. Modernizing the grid is essential, as both overall energy consumption and the share of renewable energy are steadily increasing. A higher proportion of renewables places greater demands on grid stability, making upgrades unavoidable. However, as described in the Literature Review above, this issue is not unique to Kazakhstan and is a common challenge in many countries transitioning to renewable energy.

6. Conclusions

The transition to RES in Kazakhstan is both a strategic necessity and a complex policy challenge. As a developing oil-exporting country, Kazakhstan faces mounting internal and external pressures that render its reliance on fossil fuels increasingly untenable. These pressures include recurrent oil price volatility, growing electricity demand, environmental degradation, international climate commitments, and the broader global energy transition. In this context, renewables are not merely an alternative energy option—they are critical for the country's long-term energy security, economic diversification, and environmental sustainability.

This study has shown that while Kazakhstan possesses substantial renewable energy potential, the path toward its realization is obstructed by a range of interrelated barriers. These include market imperfections (such as the highly regulated energy sector), economic and financial obstacles (such as high capital requirements and poor access to affordable finance), institutional weaknesses (including regulatory fragmentation and limited administrative capacity), and technical constraints (particularly the shortage of skilled labor and outdated infrastructure). In addition, social and behavioral factors—particularly limited public awareness and acceptance—remain underappreciated yet influential.

Importantly, these barriers do not operate in isolation. The study reveals their mutually reinforcing nature: for instance, weak institutional frameworks exacerbate financing difficulties, while low public awareness reinforces political reluctance to reform energy subsidies. Moreover, small producers and prosumers are disproportionately affected, facing regulatory burdens and exclusion from formal support mechanisms such as auctions. This calls for a differentiated policy approach that takes into account actor-specific vulnerabilities.

Despite these challenges, recent developments, such as reforms to power purchase agreements and growing interest from development banks, indicate a willingness within both government and private sectors to catalyze change. However, such efforts must be scaled and better coordinated. Targeted policy interventions should include liberalizing market conditions for small-scale producers, increasing transparency and accessibility in regulatory processes, and investing in education and vocational training to alleviate the human capital deficit in the RES sector. Equally important is the need to modernize Kazakhstan's aging energy infrastructure to ensure system reliability and grid compatibility with variable renewable inputs.

Furthermore, two strategic insights emerge from the broader context: the necessity of incorporating lessons from developed countries to circumvent common policy and regulatory pitfalls, and the need to maximize the environmental benefits of international projects, such as the BRI, to accelerate domestic renewable deployment.

This study contributes to the literature on energy transition in resource-rich developing economies by empirically identifying and thematically organizing the barriers specific to Kazakhstan. The insights generated from interviews with sector stakeholders underscore that overcoming these barriers will require not only regulatory and technical reforms, but also broader socio-economic transformations. In closing, the energy transition in Kazakhstan is inevitable, but its success is not. The country must adopt a proactive, inclusive, and multi-level strategy to address existing obstacles and unlock its renewable energy potential. Only by doing so can it ensure a sustainable energy future beyond the age of oil.

Regarding research limitations and areas of further research, the first limitation is the reliance on self-reported data. This limitation, like the others mentioned here, stems from the nature of the topic. As explained earlier, it was addressed through cross-checking responses and conducting follow-up calls to clarify and verify the answers. The second limitation is the small sample size. As noted in the Materials and Methods section, the number of individuals with a comprehensive

understanding of the energy transition in Kazakhstan is limited. However, the authors made every effort to maximize the sample size. The third limitation is the reluctance to comment on certain issues due to political or self-censorship concerns.

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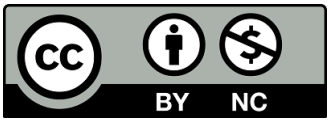

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