NHRE Deployment

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Despite globally progressing energy transition, the deployment of non-hydropower renewable energy (NHRE) in developing countries varies by country and overall is moderate. This entry aims to explain why developing economies with significant challenges in the energy sector are not actively engaged in NHRE diffusion. In doing so, the entry reviews scholarly work on renewable energy (RE) deployment in developing countries and presents a two-stage analytical framework for assessing the NHRE development status. The procedure helps assess the current situation in the national energy sectors in connection to their economic growth and development, environmental sustainability and energy security. At the next stage, the framework lets analyse the preparedness of the national energy sectors for NHRE diffusion. The analysis spans six dimensions: structure of energy sector, RE regulation, institutions and governance, capital and investment, infrastructure and business environment, and human capital. The two-stage analytical framework assists in checking the hypothesis that more advanced economically and institutionally countries are more likely to commence NHRE development.

Keywords: non-hydropower renewable enrgy ; developing economies ; analysis of renewable energy diffusion

1. Introduction

1.1. Literature Review

To frame our analysis of the determinants facilitating and impeding non-hydropower renewable energy (NHRE) deployment in Central Asia, we first present a succinct review of the existing research on developing countries. Bourcet [1] notes that there are differences between the factors affecting the deployment of renewable energy (RE) in developed and developing economies and summarizes that majority of studies prove the positive effect of the population size, RE policies, and participation in the Kyoto Protocol. In turn, the negative impact on RE diffusion is observed for traditional energy industries lobby. Income level, CO_2 emissions, energy security, financial sector development and institutional quality are found to have an ambiguous influence. Studying the determinants of NHRE diversification in 117 developing countries over the period 1980–2011, Seriño [2] shows that higher levels of per capita income, technological innovation, human capital, dependence on imported energy, and crude oil price, as well as the implementation of RE policies, promote diversification. Examining 108 developing countries between 1980 and 2010, Pohl and Mulder [3] find that NHRE diffusion accelerates with the implementation of economic and regulatory instruments, higher per capita income and better schooling levels, as well as with stable democratic regimes. Increasing trade intensity, higher levels of foreign direct investment (FDI) and official development assistance (ODA), institutional and strategic policy support programs, and rapid growth in electricity consumption delay the diffusion of NHRE. Seriño [2] and Pohl and Muilder [3] agree that the abundance of hydropower and availability of fossil-fuel resources impede diversification. Pohl and Muilder [3] identify no evidence for any influence of the level of the financial sector development and weak evidence of the positive influence of the Kyoto Protocol on NHRE diffusion. Confirming Pohl and Muilder's findings for the financial sector, Seriño [2] claims robust evidence of the Kyoto Protocol positive impact on NHRE diversification.

Regarding economic openness, which is critical for technology transfer and diffusion, Amri [4] reports the bidirectional link between RE development and economic openness. In the examined group, this aspect is relevant Kazakhstan and Kyrgyzstan, the members of the Eurasian Economic Union. Development of RE in Kazakhstan has been supported by the Eurasian Development Bank (EDB) financing and Russia's investments [5][6]. Importantly, Yao et al. [7] find that compared to developed economies, the developing countries reach the turning point on the U-shaped renewable energy Kuznets curve at a lower income level. Seriño [2] also demonstrates that the diversification of NHRE progresses faster as developing countries grow more affluent. This may be linked to the effects of technology transfer and learning-by-doing, but also to gradual reforms in heavily subsidized domestic electricity sectors. In Turkmenistan, where electricity was free of charge through the year 2019, Bahrami et al. [8] argue that the LCOE for wind (0.0435 to 0.0893 USD/kWh) opens up large exporting opportunities. Besides, for low and lower-middle-income economies, NHRE is often seen as a plausible

solution for energy cut-offs and blackouts, especially in rural areas. Eshchanov et al. [9] (p. 796) assess that, in Uzbekistan, “any need for renewable energy sources at the present time exists mainly due to the cut-offs or shortages in the traditional energy supply”.

On the flip side, NHRE deployment in developing economies with modest own means may create higher risks of new kinds of dependencies on critical materials, foreign technology, and financial resources [10][11][12][13]. Greater deployment of RE may also intensify the risks of political dependency on a key donor of financial or technological resources, or the risks of geopolitical conflicts stirred by the complexity of resource-sharing [14][15]. Studying the impacts of renewables-related development aid, Marquardt [16] distinguishes between the effects of negative fragmentation for the local-scale projects and positive pluralism for the national-level projects. Marquardt et al. [17] observe that while ODA provides expertise and financial capacity for the enhancement of energy transitions in developing countries, the aid is often loosely linked to the recipients’ goals and challenges for renewables. Marquardt [18] claims that ODA cannot force energy transition, but can become a driving force for creating the niches for technological experiments and policy innovations. Scaling up the niche level developments into full-fledged energy transitions is more successful when the donor considers the recipient’s domestic policy priorities and complex interlinkages within macro-societal structures [19][20]. Yet, Kim [21][22] holds that donors’ energy aid-giving patterns have changed markedly after the adoption of the Kyoto Protocol, and now their aid decisions are influenced by the recipient energy needs aligned with the SDG. Delina [22], Buntaine and Pizer [23] and Kim [21] demonstrate that attempting to meet the donors’ financing priorities that favor sustainable energy (the Norwegian Sovereign Wealth Fund, Saudi Arabia’s Public Investment Fund, European Investment Bank, among others), the developing nations update their climate policies to become eligible for the ODA.

NHRE deployment dilemma in fossil fuels-rich (FFR) developing economies (in our study, Kazakhstan, Turkmenistan and Uzbekistan) is multidimensional. Boute and Zhikharev [24] argue that incumbent energy companies acquire the powers of vested interest groups in solar PV manufacturing sector and accelerate RE diffusion in Russia. Aligning with Moe's [25] arguments drawn for other cases, Boute and Zhikharev [24] (p. 1) believe that “(t)he manufacturing of clean energy equipment rather than the decarbonization of the energy system, drives Russia’s renewable energy policy”. This assessment is supported by the findings that the development of NHRE is associated with larger innovation intensity in the energy sector and the economy at large [2][26][27]. Explaining the rationale behind, Mäkitie et al. [28] think that the turbulences at the commodities markets drive the reorientation of the incumbent national fossil fuel industries towards locking out the lower-carbon alternatives.

The diffusion of renewable energy proliferates in economies with adequate technological, socio-economic, and political institutions. The most critical for energy transitions institutional traits involve a decent degree of flexibility and adaptability [29][30][31]. The problem in energy rent dependent countries is that their governments are reluctant to initiate transformations because of the associated risks of destabilization of the incumbent authority and propagation of political and socio-economic turbulence [11][32]. In authoritarian rent dependent economies, the political elites construct fiscal systems upon a heavy reliance on the taxation of resources. This creates an image of a state being paternalistic vis-à-vis its citizens (ample examples of this kind are the rationed per capita or per household quantities of free of charge electricity, gas, and gasoline). In reality, however, such a system fosters rampant clientelist traditions and hinders governments’ accountability [33][34]. It is for the virtues of interdisciplinary frameworks instrumental for the analysis of complex phenomena of NHRE diffusion that the concepts of institutional theory [35][36], political economy [37] and varieties of capitalism [38][39][40] are increasingly appreciated. The argument goes that RE development can be enhanced by the efficient institutions and, in turn, the sector can become a driver for a range of positive shifts in the national energy sector and the economy at large. On the contrary, the RE sector may be affected by the poor practices becoming yet another channel for syphoning off the national wealth [41][42]. Putting this in perspective, developing nations who lack their own financial capacities, tend to rely on FDI and ODA when deploying RE innovations. The effectiveness of external financing is influenced by the quality of national institutions [43].

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

Putting these observations in perspective, a variety of determinants turns Kazakhstan into the fittest candidate for the NHRE development. A number of factors seem to be favoring NHRE deployment in Uzbekistan and Turkmenistan. While Kyrgyzstan and Tajikistan appear to be less equipped to engage in RE diversification, their prospects for doing so are improving. In the following section, we outline the framework, upon which we check our hypothesis that more developed economically and institutionally Central Asian countries are more successful in NHRE deployment.

1.2. Methodological Framework and Data

To assess the Central Asian economies' NHRE deployment status, we apply the two-stage analytical framework, which incorporates insights from the reviewed existing research and builds upon the adopted practices [44]. First, we evaluate the ability of national energy systems to meet the needs of respective Central Asian economies across three interacting dimensions: economy, security, and sustainability (Table 1). At the second stage, we assess the countries' preparedness to embrace NHRE. In doing so we examine the structure of the incumbent energy systems and analyze the adequacy of the existing RE policies, intuitions, investments, infrastructure and human capital.

Table 1. Analytical Framework Energy System's Performance—Deployment Readiness (Source: author, adapted from [44] (p. 31); [45]; [46] (pp. 185–187)).

Characteristics	Dimensions	Key Indicators
Energy system performance	**Economy**	**Economic growth, %** **Population growth, %** **Electrification rate, % of population** **Energy rent, % to GDP** **Energy subsidies, % to GDP** **Net fuel exports, % of TPES**
	Energy Security	**Net energy imports, % of TPES** **Diversity of energy exports/imports** **Quality of electricity supply**
	Environmental Sustainability	**Energy intensity** **CO_2 intensity**
NHRE deployment readiness	**Energy System Structure**	**Energy supply per capita** **Electricity system flexibility, shares of hydro, gas and oil** **Share of electricity from coal** **Share of electricity from NHRE** **Share of global fossil fuels reserves, %**
	Regulation and Political Commitment	**State goals** **Factors affecting state goals (dependencies on external factors)** **NDC commitment** **RE policy stability** **Energy efficiency regulations** **RE regulations** **Energy access regulations**
	Institutions and Governance	**State capacity and stability** **Special interests** **Corruption** **Rule of law** **Credit rating**
	Capital and Investment	**Investment freedom** **Access to credit** **New NHRE capacity built, % of change**
	Infrastructure and Business Environment	**Infrastructure for extraction, transportation, conversion and use** **Technology availability** **Logistics performance** **Innovative business environment** **Internet users, % of population** **Mobile telephone, units per 100 people**
	Human Capital	**Education quality**

For the quantitative assessments, we employ a vast range of data sources (Appendix A). The country-level analysis additionally incorporates relevant data published by the national ministries of energy (or respective agencies in charge of RE regulation) and national statistical services. State-owned energy companies' information helps comprehend the

hierarchy of the national energy sectors and the structure of domestic electricity markets. Out of the five countries covered by this study, Turkmenistan has the sparsest data.

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

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