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# Impact of storage technologies on renewable energy integration in Kazakhstan

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**Abstract**

Utilizing electricity from renewables requires significant back-up generating capacity for the reason that solar and wind energy outputs could vary throughout the days, seasons and affected by weather conditions. This paper examines the impact of storage technologies integration to the power system of Kazakhstan based on optimization model. System components involve nodes and regions allowing the model to interact among these division sets trough transmission lines. Using the data elaborated by the Kazakhstani Electricity Grid Operating Company (KEGOC) the model allows to observe the nodal level interconnection of the spatial characteristics of the power system till 2050. Model results indicate that storage facilities could improve the reliability of power system and reduce electricity costs by storing electricity at the low electricity demand hours and low prices for utilizing stored electricity at peak demand hours. The proposed model determines the optimal way of implementation of energy storage technologies and renewable energy sources, their capacity and amount of investment. With the assumption that the generation from conventional power plants is fixed on the level of 2015 we have tested various levels of implementation of storage technologies. The resulting optimal ratio of installed capacity of storage to installed capacity of renewables is between 10-15%.

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*Keywords:* storage system integration; modeling; renewable energy; Kazakhstan

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## 1. Introduction

In the next decade, Kazakhstan, being one of the big producers and exporters of the hydrocarbon resources, should accelerate technological modernization of the energy system and development of energy saving technologies. Kazakhstan is expected to be one of the major coal producers during the next decade. Currently Kazakhstani electricity production accounts for 76 power plants with installed power capacity of around 20.6 GW. However, the available capacity is 17.1 GW (16.9% less than its installed capacity) [1]. This capacity drop is explained by the high wear out of the generation units and requires a thorough management plan.

In addition, energy demand studies forecast a growth of energy consumption of both industry and public sectors. For example, according to [2], electricity demand in 2021 will grow up to 24% in comparison with 2013. Demand growth rates are different in the South region (high) and in the North region (low). Nevertheless, generation of electricity is mainly concentrated in the North and Central Kazakhstan. The electricity generation is mostly performed by utilizing the existing generating units in the North to their highest capacity. This situation affects negatively the development of the power sector of Kazakhstan.

Significant policy measures were undertaken nationally for promoting renewable energy sources (RES) penetration. With the scope to improve energy efficiency of the power system and reduce greenhouse gases emissions, "The concept of the transition of the Republic of Kazakhstan to Green Economy" was introduced by President of the Republic of Kazakhstan. By 2030 it is expected to install 4.6 GW of wind and 0.5 GW of solar capacities [3]. Feed-in tariff scheme were introduced by Kazakhstani Government in 2014. Separate standard rates were calculated separately for wind and photovoltaic, small hydro and biogas generations [4].

Successful implementation of governmental programs will depend on detailed action plans determining the investments needed and understanding of the impact of each measure. One of the key measures could become an integration of storage technologies. Storage technologies loaded at low energy demand and utilized at high demand periods have a positive effect in management of energy networks [5].

## Nomenclature

| | | | |
|---|---|---|---|
| **Indices/Sets** | | $H_{l,n}$ | flow sensitivity matrix |
| $p$ | energy generating units | $avaPV_{t,n}$ | availability of PV in node n (%) |
| $g$ | energy generation plants | $avaWP_{t,n}$ | availability of Wind Power in node n (%) |
| $l$ | transmission line | Zh | factor which represents 8760 hours |
| $n$ | node | | |
| $k$ | object | **Positive variables** | |
| $t$ | time interval | $EI_{p,y,t}$ | electricity generation from plant p in time period t |
| $y$ | years | $EN\_DUMMY_{n,y,t}$ | dummy electricity generation in node n in time period t |
| $ft$ | type of fuel | $EWP_{n,y,t}$ | electricity generation from WP in the year y in time period t |
| $s$ | technology | $EPV_{n,y,t}$ | electricity generation from PV in the year y in time period t |
| **Subsets** | | $CapWP_{n,y}$ | capacity of WP in node n in the year y |
| $PN_{p,n}$ | nodes to plants | $CapPV_{n,y}$ | capacity of PV in node n in the year y |
| **Parameters** | | $CapStor_{n,y}$ | capacity of storage systems in node n in the year y |
| $c_p$ | marginal cost for generation plant p (KZT per MWh) | $gs_{n.y.t}$ | discharging of storage systems |
| $FC_s$ | fixed cost of new technology | $ls_{n.y.t}$ | charging of storage systems |