# Renewable energy sources in future energy balance of the republic of Kazakhstan

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**Abstract.** The article describes the main factors determining the development of renewable energy sources in the world. The assessment of the applicability of foreign RES development strategies to Kazakhstan's energy system has been made. The main tasks facing Kazakhstan's energy system with large-scale implementation of renewable energy were formulated. On the basis of the analysis and performed calculations recommendations and basic principles have been made on development strategy of renewable energy sources in the Republic of Kazakhstan.

## 1 Introduction

Renewable energy is one of the fastest growing sectors, attracting more than $ 250 billion of capital investments every year worldwide. Many countries, including developing ones, set ambitious long-term goals for the development of renewable energy sources (RES). According to the UN, by the middle of the century, perhaps more than half of humanity's energy needs will be provided through renewable sources [1].

According to the report [2], in 2015, investments in the production of electricity from coal and natural gas amounted to about $ 130 billion, which is less than half of capital investments in renewable energy sources, amounting to $ 286 billion.

It is noteworthy that the amount of investment in RES was higher in developing countries than in developed countries. In Brazil, South Africa, Mexico, Chile, Honduras, Morocco, Pakistan, the Philippines and Uruguay – investment ranged from $500 million up to $7 billion. Investment in developing economies rose 19% to $156 billion, while in developed countries decreased by 8%, to $130 billion (for example, in Germany investments totaled $8.5 billion).

Kazakhstan also creates favorable conditions for the development of renewable energy sources. According to the plans of the government of the Republic of Kazakhstan, the share of renewable and alternative energy sources in total electricity production should be brought to 3% by 2020, 30% by 2030 and 50% by 2050 [3].

The purpose of this paper is to analyze the factors affecting the development and optimal level of renewable energy sources in the country's energy balance.

## 2 The factors in the development of renewable energy sources and the current situation in the world

One of the main factors stimulating RES development is to reduce greenhouse gas emissions in energy production, to combat global warming. Currently, it is believed that the probability that a large part of the temperature change caused by increases in greenhouse gas concentrations due to human activities is 90 %. The following estimate is given in the reports [2,4]: "It is extremely likely that human influence was the main cause of warming observed from the middle of the 20th century".

However, a significant difference in the proportionality between investments in renewable energy sources and the level of CO2 emissions in different countries shows different strategies for increasing the volume of RES despite environmental issues.

Another important factor stimulating the development of renewable energy sources is the desire of countries to reduce their dependence on external energy supplies. For this, energy saving and more complete use of own energy resources are used as the main methods. In modern conditions, renewable energy sources also contribute to the solution of this problem.

As a main measure of energy conservation, the direction was chosen to structural reorganization of the economy with a reduction in energy-intensive industrial production and an increase in the share of services. However, energy conservation, which is very effective at the national level, does not have a significant impact on the world energy consumption level, as the reduction in the production of energy-intensive products in developed countries causes an increase in energy consumption for

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the production of relevant products in other countries of the world.

Substitution of fossil fuel-based generation by nuclear energy is not always possible, as the use of nuclear power plants is directly connected with the policy implemented by the State and often depends on public opinion.

It is expected that at the global level, interest in renewable energy sources will continue to increase due to the growing demand for energy, the reduction of proven fossil fuel reserves, as well as environmental problems. Currently, more than 138 countries identified RES as development goals at the national level. The increase in the share of RES occurring despite falling global energy prices and the allocation of fossil fuel subsidies.

At the current stage of development, renewable energy sources (excluding large hydropower stations and geothermal power plants) in most cases are difficult to compete economically with traditional energy industry. Therefore, in all countries, developing renewable energy sources, there are a variety of measures to support them, artificially increasing their competitiveness. The most popular measure of support is the establishment of special high tariffs for electric power produced by renewable energy sources, which guarantee the payback of the project. Also, it is often practicable to compensate for the cost of connecting RES to electric grids.

Currently, preferential tariffs for RES power plants are stipulated in the legislation of many countries, including not only developed European countries, but also China, India, poor African countries like Kenya and Tanzania, as well as Iran and Algeria, rich in hydrocarbons [5].

The result of all these incentive measures is the most active development of renewable energy sources in the world over the past decade.

## 3 Features of the energy system of Kazakhstan. Limitations and risks for large-scale penetration of renewable energy sources

The development of the energy infrastructure in Kazakhstan was significantly determined by the presence of large reserves of cheap coal and gas, which makes the share of electricity generation using fossil fuels at a high level.

First of all, increasing the share of RES brings the following technical problems to the energy system:

Complication of dispatching control due to the increase in the number of generation nodes and the transformation of previously passive distribution networks into active ones [6].

Negative impact of RES on the reliability of energy system operation, the complexity of the UPS operation modes forecasting.

The need for reconstruction of networks with mass input of renewable energy sources.

Large volumes of variable generation of RES are able to cause power leaps in interfaces due to a drastic change in the production mode. This requires an analysis of the effect of RES on irregular power fluctuations, as well as the consideration of possible power leaps in determining the power transfer limits in the interfaces. There is a need to maintain large reserves of maneuverable generation or reserve transmission capacity in interfaces.

When using foreign experience of introducing RES, it is necessary to take into account the peculiarities of Kazakhstan's energy system.

First, in the conditions of a sharply continental climate, the main part of the energy demand is made up of thermal energy, which exceeds the demand for electricity several times. A significant part of the energy (about 40%) is generated by CHP plants that operate on a thermal schedule and can not be used to cover unbalances in the generation of RES. Renewable generation based on solar and wind energy, partially covering the demand for electricity, is not able to provide heat in the required volumes. Since in most Western countries there is no centralized heat supply system, it is unacceptable to directly distribute the results obtained in European countries to Kazakhstan.

Secondly, for concentrated energy systems of Western countries, the key limitation is the current loading, while for Kazakhstan energy system the determinative limitation for the transmission of electricity through the backbone network is steady state stability. Considering that the total capacity of RES, which is supposed to integrate into the UPS of Kazakhstan, significantly exceeds the natural transmission capacity of transmission lines (even 500 kV), this will be one of the main problems in ensuring the sustainability of the UPS of Kazakhstan in the development of RES. Definitely this will require a fundamentally new approach to load flow management, primarily automatic.

In IEA report there are counter-arguments against challenges described above [7]. However, statements are not accompanied by strong evidence. In the conditions of the full load of power transmission lines according to steady state stability limits due to the highly echeloned and complex automation, it is impossible to state that the deviations of RES are safe for the power system.

An uncontrolled increase in the share of RES due to state support can lead to a significant increase in electricity tariffs, which at some point may push consumers to avoid centralized power supply and switch to cheaper small generation, including operating in isolation from the UPS. With sufficiently high tariffs, large consumers can start installing own power plants, refusing from centralized power supply services. This is especially true for areas with significant hydrocarbon reserves with a large-scale development of the gas transportation system.

The creation by consumers of own generation will not pass without a trace for the UPS, which will lose the large and strong entities of the wholesale market. As a result, the remaining participants of the grid will increase their workload to maintain the conditions for the operation of the entire power system.

In addition, the priority given to renewable energy leads to substitution of existing generation and a decline in the economic returns of traditional power plants, whose construction becomes less attractive for investors. While RES is not able to be created and operate without the support of traditional maneuverable generation.

Renewable generation, due to its uncertainty, requires reserve capacity to cover unbalances. Theoretically, the variability of renewable sources can be compensated for by the flexibility and modulation of the fleet of stations. However, in practice, this is difficult to implement, because these stations have own technical and economic limitations. Power storage significantly increases the capital investment in the construction of RES.

Countries with predominantly coal generation, which are most interested in reducing CO2 emissions, are now facing a shortage of maneuverable power plants. In the absence of a sufficient volume of regulatory capacity, it will be necessary to conclude contracts for regulating services with adjacent power systems, the costs of which are difficult to forecast and will be included in the tariff.

For the energy system of Kazakhstan, the contradictions between the desire to introduce large volumes of renewable energy sources and ensure the reliability of the UPS become obvious. Therefore, it can be argued that the spontaneous growth of renewable energy without a scientific study is the main problem.

The opinion expressed in 1975 by academician P. Kapitsa regarding the prospect of using renewable energy as the main source of electricity is also relevant today [8]. As noted by P. Kapitsa, the generation of electricity from RES in practice for high-power engineering is limited by the limited value of the energy flux density (1).

The density of incoming energy is limited by the physical properties of the medium through which it is transmitted. In a material medium, the energy flux density U is limited by the expression:

$$\mathbf{U} < \mathbf{v}F, \qquad (1)$$

where **v** is the speed of propagation of energy, F-energy density. **U** is the vector value. When stationary processes **div U** determines the amount of energy conversion in another form.

Direct conversion of solar energy into electricity for high-power engineering is associated with a limited value of the energy flux density. In this case the speed of propagation of energy **v** is almost equal to the speed of light, however, the energy density is low.

## 4 Impact of large-scale RES penetration. Modeling of influence with respect to UPS of Kazakhstan

Important results were obtained by the authors in [9]. In the course of the research, a mathematical model was created, the input parameters for which were: material capital, fossil fuel resources and infrastructure required for RES.

In this model, the growth of material capital is possible in the presence of a surplus of electricity, and the resources of fossil fuels take into account the initial energy costs for the creation of RES and the cost of production over time. Parameters: fossil fuel resources and the cost of production are necessary to define a limit for the extraction of fossil fuels. In this paper, for the parameter "infrastructure required for RES", the most important characteristic is "renew return" (RE), which characterizes the return of RES energy relative to the spent energy for RES creation.

Of the more than 100 simulated scenarios for more than a quarter have shown the unstable state of the system when you enter RES, i.e. the economy of the country was unable to meet demand for electricity as the depletion of fossil fuel reserves. The equilibrium was ensured by the introduction of renewable energy sources in the event of signals about a shortage of electricity as the resources of fossil fuels were depleted. Simultaneously, the simulation results showed a significant effect on the result of the dynamics of the introduction of renewable energy as the deficit approaches. With the slow introduction of renewable energy sources, the country's economy was not able to provide material resources and energy for the creation of renewable energy infrastructure because of the decline in electricity production from the traditional sources. Based on a series of sustainable scenarios, it can be concluded that the maximum amount of renewable energy is determined not by the technical limitations of the energy system, but by the dynamics of the use of the existing infrastructure and depletion of fossil fuels.

In the case of Kazakhstan, the following time contours of RES development can be formulated. Based on the forecasted balance of the UPS of Kazakhstan for a seven-year period (until 2024) [10], in the absence of input of generating capacities, a power shortage of 180 MW occurs by 2022 (excluding reserves). With scheduled inputs of traditional generation, there is no electricity deficit in the next seven-year period. Given the competitiveness of RES, it is possible to replace part of the traditional generation with renewable energy sources.

Given the expected power deficit and the timing of the implementation of renewable energy projects in 2022, the deadline for the beginning of active renewable energy input is 2021. However, given the availability of fossil fuels, the type of energy source (for example, nuclear power plants) should be carefully determined, and in case of non-competitiveness of renewable energy sources, it is necessary to postpone the mass entry of renewable energy sources at a later date.

The introduction of renewable energy sources on a competitive basis (without the creation of benefits) can be carried out at any time, as with the competitiveness of renewable energy sources one can speak of the inefficiency of traditional generation.

Kazakhstan power system consists of three zones: North, South and West (Figure 1).

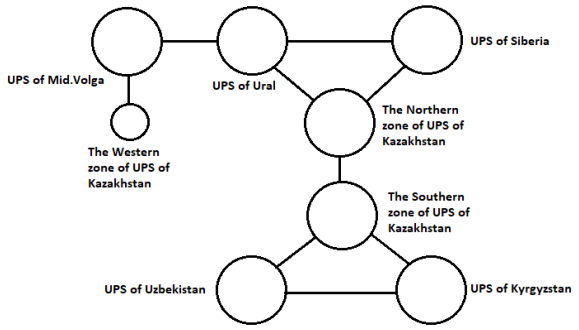


**Fig. 1.** The simplified scheme of the Unified Power System of Kazakhstan.

The Southern zone is energy-deficient by about 1500 MW, and covers the deficit from the Northern zone. The main problems with stability in UPS of Kazakhstan are observed in interface, connecting the Northern and Southern zones. The planned significant increase in renewable energy in the South zone has the potential to exacerbate existing problems with stability. While maintaining the current dynamics of input of wind farms and PVs, by 2021 the maximum instantaneous output of PVs and wind farms will be about 7% of the total generation of the country and 45% in the Southern zone. The increase in the volume of renewable energy requires a greater maneuverable capacity of traditional stations to cover the net load, since solar generation changes the form of the daily consumption schedule in the direction of decreasing the noontime demand. Net load is power consumption, excluding generation from renewable energy sources, i.e. it is a demand that must be covered by traditional stations. By 2021, on the day of maximum consumption at maximum output from PVs, the required capacity of traditional stations to cover the evening peak of the net load will increase by 800 MW, i.e. by 65% (Figure 2).

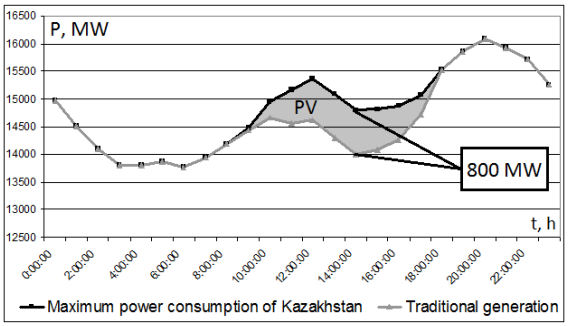


**Fig. 2.** Daily schedule on the day of maximum load, taking into account the maximum output of PVs (2021).

A situation was simulated in which the growing power consumption in the South zone is covered exclusively by introducing RES, without introducing traditional capacities, and the effect of reducing parts of the variable generation on the stability is considered.

In power systems of developed countries with a high degree of introduction of RES, the accuracy of predicting variable generation is about 10%. The accuracy of the forecast strongly depends on the amount of historical data and modern means of climate monitoring. At the initial stages of penetration of renewable energy in Kazakhstan it will be difficult to achieve high accuracy of forecasting.

The loss of a part of RES generation in the South zone causes a power leap in the North-South interface. At a consumption level of 2021, the transmission capacity of the North-South interface allows reserving possible losses of generation in the Southern zone due to the flow from the North Zone.

If the annual growth of consumption in the South zone is maintained at 5%, the planned increase of the RES is not able to cover the deficit. The growing deficit will lead to an increase in power flow across the North-South interface and a decrease in interfaces stability margin. At the same time, the increasing share of renewable energy in the Southern zone leads to an increase in the possible power leaps in the North-South interface.

With the increase in consumption and the increase in the share of renewable energy sources, critical power leaps can occur with a smaller percentage of the switched-off generation of RES. In 2031, the loss of 80% of renewable energy will lead to a violation of transient stability, due to power leaps on the North-South interface. In 2035, the loss of 50% of renewable energy will lead to a violation of transient stability (Figure3).

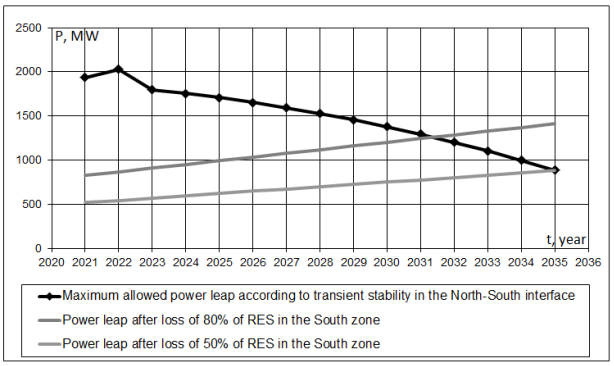


**Fig. 3.** Power leaps at various %% off of RES in the Southern zone.

Even if the entire deficit growth in the South zone is covered by introducing RES, the problems with stability will remain relevant. In this case, it will be necessary to introduce a larger amount of RES, which will also lead to an increase in the possible power leaps (Figure 4).

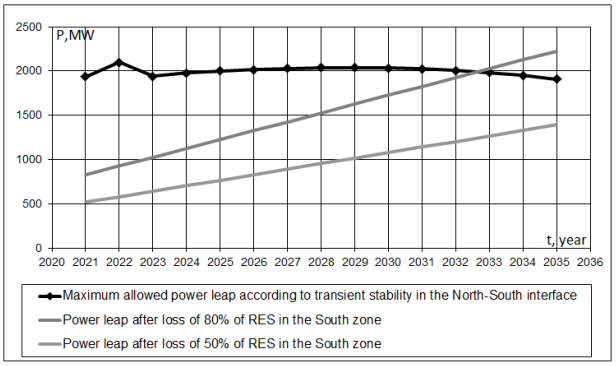


**Fig. 4.** Power leaps at various %% off of RES in the Southern zone.

The emergence of a powerful stable generation in the southern zone is capable of relieving North-South interface and providing a larger reserve of capacity, which will ensure the safe operation of the Southern power district when introducing large volumes of RES.

Obviously, coverage of imbalances of energy-deficient areas exclusively at the expense of renewable energy is impossible. Proceeding from this, in parallel with the large-scale commissioning of renewable energy in the Southern zone of the UPS of Kazakhstan, it is necessary to strengthen the links or enter synchronous generation of commensurate capacity for unloading interfaces.

## 5 Conclusion

Many countries embarked on a large-scale implementation of renewable generation. However, when planning the development of the energy system of Kazakhstan, it is inadmissible to copy the energy strategies of other countries. When planning a model for the development of renewable energy in a particular country or region, the features of the power system configuration should be taken into account.

On the basis of the analysis, the following basic principles can be formulated when introducing renewable energy sources into the energy system of the Republic of Kazakhstan:

• The transmission capacity of the interfaces must be selected taking into account the possible power leaps caused by variable generation.

• When planning the operation modes, it is necessary to take into account the volume and rate of change of the maneuverable generation of regulating stations.

• Coverage of imbalances of energy-deficient areas exclusively at the expense of renewable energy is impossible. In parallel with the large-scale commissioning of renewable energy in energy-deficient areas, it is necessary to strengthen the links or introduce synchronous generation of commensurable capacity for unloading interfaces.

• Increasing volume of variable generation will require involvement of additional regulation stations or contracting regulation with neighboring countries. In Kazakhstan currently there is no sufficient maneuverable generation. Therefore, the development of renewable energy requires the modernization of the market model in order to create conditions for the development of maneuverable power plants.

• The penetration of renewable energy in isolated parts of the UPS or in any parts on a competitive basis (without the creation of benefits) can be carried out at any time, since with the competitiveness of renewable energy sources with traditional energy, one can speak of the extreme inefficiency of the latter.

Taking into account the peculiarities of Kazakhstan power system, it becomes obvious that an unreasonable, constant increase in the share of renewable energy in the production of electricity is not an optimal option for the development of the energy system. Insufficiently thought-out policy of constant increase of the share of RES in the power system in pursuit of nominal indicators can disrupt the entire electric power sector. Until the capital costs for the creation of renewable energy can be justified by the energy received for converting solar or wind energy, RES will not contribute to the sustainable development of the energy system and the economy of the country as a whole.

To achieve maximum reduction of harmful emissions with minimal negative impact on the energy system, the use of combinations of different technologies, primarily nuclear power, should now be considered.

Thus, the penetration of renewable energy will require a significant change in the entire energy industry of the country, both in terms of technology, and in terms of economic and legal relations.

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