Prospects for renewable energy curtailments in Kazakhstan: the role of power plants and networks

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THANKS TO THE POLICY OF SUPPORTING THE DEVELOPMENT OF RENEWABLE ENERGY SOURCES, INCENTIVES AND REDUCING THE COST OF TECHNOLOGIES, THE SHARE OF RENEWABLE ENERGY SOURCES IN KAZAKHSTAN HAS INCREASED SIGNIFICANTLY. THUS, ACCORDING TO THE MINISTRY OF ENERGY OF THE REPUBLIC OF KAZAKHSTAN, ACCORDING TO THE RESULTS OF THE FIRST HALF OF 2024, THE SHARE OF RENEWABLE ENERGY IN ELECTRICITY GENERATION REACHED 6.5% WITH AN INSTALLED CAPACITY OF 2.9 GW OF RENEWABLE ENERGY (WPP – 1.4 GW, SPP – 1.2 GW, SHPP – 0.27 GW)[1].

Thanks to the policy of supporting the development of renewable energy sources, incentives and reducing the cost of technologies, the share of renewable energy sources in Kazakhstan has increased significantly. Thus, according to the Ministry of Energy of the Republic of Kazakhstan, according to the results of the first half of 2024, the share of renewable energy in electricity generation reached 6.5% with an installed capacity of 2.9 GW of renewable energy (WPP – 1.4 GW, SPP – 1.2 GW, sHPP – 0.27 GW) .

According to the Energy Balance of the Republic of Kazakhstan, by 2035 (Order of the Ministry of Energy of the Republic of Kazakhstan No. 44 dated 30.01.2023), the total installed capacity of WPP and SPP is planned to increase to 7.5 GW, including

[1] *Settlement and Financial Center For Renewable Energy Support 24.07.2024 https://rfc.kz/ru/press-center/news/163797*

wind WPP up to 5.3 GW and SPP up to 2.2 GW. In addition, this balance does not take into account about 3.5 GW of WPP and 0.4 GW of SPP, planned for sale in accordance with the Auction Plan for 2024-2027 (Order of the Ministry of Energy No. 187 dated 23.05.2023), as well as such large projects as ACWA Power – 1 GW WPP, CPIH – 1 GW WPP, WPP Masdar – 1 GW, Shelek WPP – 1 GW.

It is well known that renewable energy is a variable source of generation that is not fully amenable to dispatching, with a characteristic forecasting error, therefore, the integration of a large volume of renewable energy into the power system can lead to certain restrictions associated with insufficient network capacity and maneuverability of traditional power plants. In this case, with excessive generation in the power system, the principle of maintaining its stable operation (balance of consumption and generation at each moment of time) forces the system operator to limit the generation of renewable energy sources and accept less wind or solar energy than the resource allows.

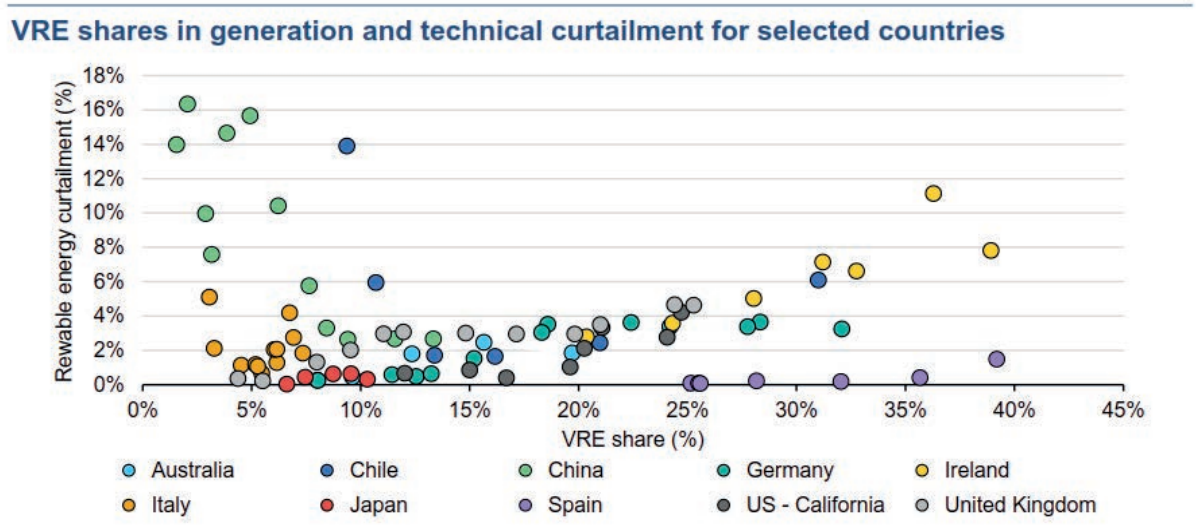
Curtailment means a forced reduction in the volume of wind or solar energy generation to a value lower than is potentially available at the moment.

Thus, the successful integration of a large volume of renewable energy into the energy system is associated with the need to introduce institutional changes, introduce market incentive mechanisms, transform the network topology, increase its capacity and flexibility, the structure of traditional generating capacities with an emphasis on the development of maneuverable sources, and improve operational activities. In case of delay in the implementation of these changes, renewable energy curtailments can reach significant volumes.

Renewable energy curtailment generation has a direct impact on the attractiveness of the project, and when concluding a take-or-pay contract, consumers will be forced to pay for ungenerated electricity.

International experience shows that in a number of countries with high rates of renewable energy development, with an increase in the share of electricity from renewable energy sources, the share of curtailments on their generation also increases (Figure 1.)

Figure 1. Dependence of the volume of renewable energy curtailments on the degree of their penetration



Source: Renewable Energy Market Update Outlook for 2023 and 2024. IEA

Thus, the share of curtailments on WPP/SPP generation in the future, with a degree of RES penetration of 30%, can reach 6-7%.

In this article, Energy System Research LLP has estimated the expected volume of renewable energy curtailments for 2030 – 2035, taking into account the indicators of the Energy Balance of the Republic of Kazakhstan until 2035, the main indicators of which are presented in the table below (Table 1).

Table 1. The main indicators of the Energy balance of the Republic of Kazakhstan until 2035, GW

Name	2030	2035
Load	**23.2**	**24.8**
Northern zone	**14.3**	**15.3**
Southern zone	5.8	6.3
Western zone	3.1	3.3
Installed capacity of power plants	**41.2**	**44.3**
Northern zone, including	24.1	24.5
WPP	2.7	3.0
GTPP	0.7	0.7
HPP	1.8	1.8
sHPP	0.1	0.1
CCGT	0.4	0.4
SPP	0.4	0.4
CHPcoal	12.1	12.1
TPP Gas	0.3	0.3
TPP coal	5.6	5.6
Southern zone, including	10.3	13.1
NPP	0.0	2.8
WPP	1.5	1.5
HPP	0.8	0.8
sHPP	2.1	2.1
CCGT	0.9	0.9
SPP	1.5	1.5
CHPcoal	0.02	0.02
TPP Gas	3.5	3.5
TPP coal	0.02	0.02
Western zone, including	6.7	6.7
WPP	0.8	0.8
GTPP	2.7	2.7
CCGT	1.0	1.0
SPP	0.3	0.3
TPP Gas	2.0	2.0

To determine the possible scope of WPP/SPP curtailments, a model was created that allows an analysis of hourly load coverage by power plants, taking into account:

- configurations of the load profile of each area,
- variable nature of renewable energy sources,
- regulating and ramping capabilities of existing and prospective traditional power plants for 2030-2035,
- throughput of weak sections,
- transfer capability of energy storage systems (ESS).

The simulation results were used in carrying out research on the operation of the power system, as well as in project approval by System operator the projects of Mirny WPP, Acwa Power WPP, Shelek WPP, etc.

The main assumptions made in the model are presented below.

Generation

Analysis of the maneuverability characteristics of existing power plants showed a wide range in the rate of power gain and discharge in %/min of installed capacity (Table 2). Significant variation in characteristics is due to equipment wear or involvement in the regulation of base power plants.

Table 2. The ramp up/ramp down rates of power in %/min of the installed capacity of existing power plants

Zone	Type	Power ramp up, %/min	Power ramp down, %/min
ICS North-South	HPP	0-8%	0-12%
	GTPP	3-9%	3-18%
	CPP	0-21%	0-18%
	HPP	3-50%	3-50%
West	GTPP	1-50%	1-50%
	CPP	0,5%	0,5%
	TPP	0-6%	0-2%

The values of the accepted maneuverable characteristics of promising power plants in % of Pinst and the power ramp up/ramp down rates %Pinst/min are shown in the table below by type (Table 3).

Table 3. Maneuverability indicators for promising power plants

Type	Max. winter load	Max. summer load	Min. winter load	Min. summer load	Power ramp up, % Pinst/min	Power ramp down, % Pinst/min
CCGT	90%	90%	40%	40%	5%	5%
GTPP	100%	100%	20%	20%	10%	10%
TPP	90%	60%	60%	30%	1%	1%
CPP	90%	90%	40%	40%	1%	1%
NPP	85%	85%	85%	85%	0%	0%
HPP (regulating)	100%	100%	0%	0%	10%	10%
HPP (counterregulator)	70%	40%	10%	10%	1%	1%

Load

Configuration of the prospective load profile was adopted on the basis of the 2021 reporting diagram. The results of the analysis of extremes and derivatives of hourly load data for 2021 are presented in the table below (Table 4).

Table 4. Indicators of hourly load data of power system of Kazakhstan for 2021

Name	Summer min	Spring min	Autumn max	Winter max	Power ramp up, MW/min	Power ramp down, MW/min
Western zone	1325	1287	1983	2079	6,9	6,2
Northern zone	6511	6747	9765	10047	8,9	11,4
Southern zone	2014	1935	3969	3957	18,5	16,3
ICS North-South	8683	8825	13646	13848	24,1	21,8

The graph of the total load of consumers of the North-South and Western zone ICS is characterized by a daytime and evening peak:

- daytime peak load (Astana time) - 10:00 – 13:00 for the North-South ICS, 11:00 - 15:00 for the Western zone
- evening peak load (Astana time) – 18:00 - 22:00 for the North-South ICS, 20:00 - 23:00 for the Western zone
- The number of hours of use of the maximum load T max is 7060 hours for the North-South ICS and 6970 hours for the Western zone.

RENEWABLE ENERGY GENERATION PROFILE

The hourly profile of renewable energy generation was calculated using specialized software PVSyst - for SPP, WindPRO - for WPP, according to historical data on the watercourse – for sHPP.

INTERSTATE FLOW RATES

Analysis of the work of the National Grid of Kazakhstan showed that the unbalances were in the range of ± 1000 MW and were covered by the exchange flows of power with the energy systems of neighboring states. However, taking into account contractual obligations on interstate flow rates in the amount of ± 150 MW from RF and ±50 MW from CA, the export/import range has been adopted in the amount of ± 150 MW for further extension.

THE TOPOLOGY OF THE ELECTRICAL NETWORK

At the 2030 stage, in order to unite the Western Zone with the North-South ICS of Kazakhstan, it is planned to construct an intersystem 500 kV overhead line Karabatan-Ulke, which will ensure the exchange flows of power between Western Zone and North-South ICS.

Taking into account the planned unification, modeling of the coverage of the prospective load for 2030 and 2035 was performed for National Grid of Kazakhstan including Northern, Southern and Western zones, taking into account the limited capacity in:

- North-South transit (L-5300, L-5320, L-5400).
- Beineu-MAEK area (L-2075, L-2085)
- Inder-Pravoberezhnaya area (L-2540).

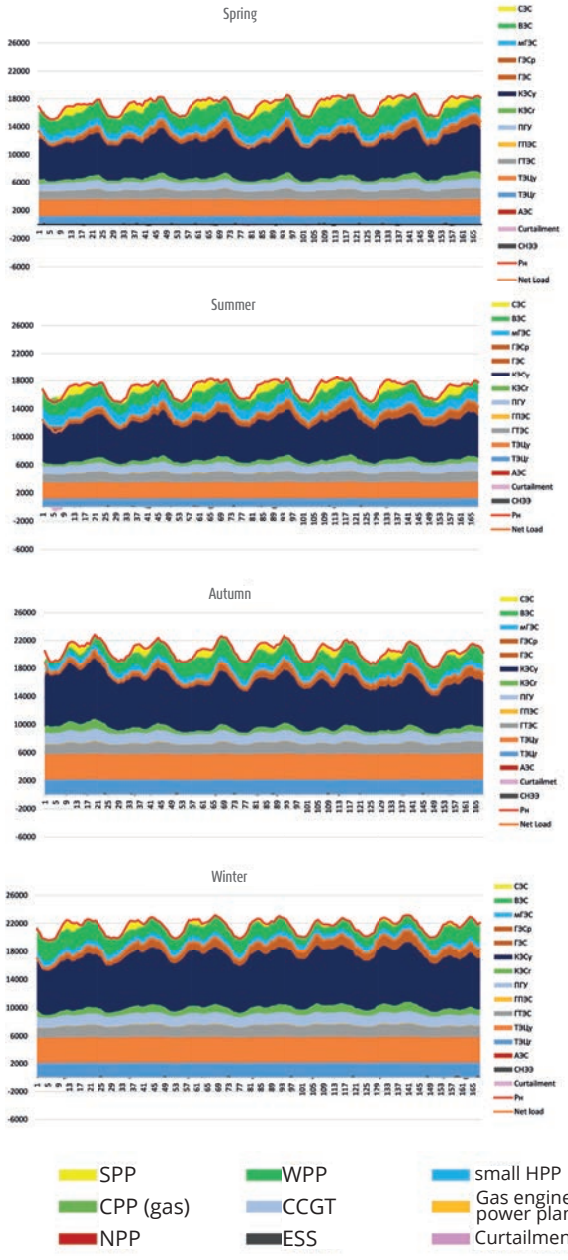
Hourly coverage schedules for 2030 and 2035 for 7 days of each season are shown in the figure below (Figure 2).

The analysis of the results of the performed simulation of the dispatching of power plants at the level of 2030-2035 allows us to draw the following conclusions:

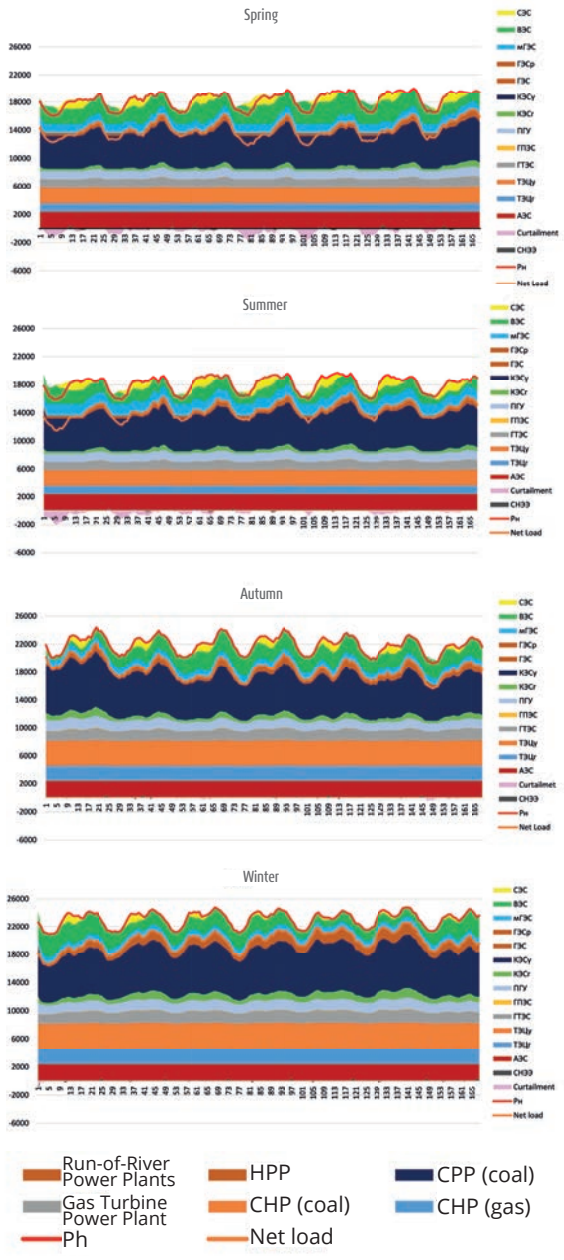
- The main factors influencing the volume of curtailments of the WPP/SPP are the regulating range of traditional power plants, as well as the presence and magnitude of the permitted range of imbalance between the power system of Kazakhstan and power systems of neighboring states;
- Taking into account the planned significant development of WPP/SPP in the Southern Zone in the summer and spring seasons for North-South transit by 2030-2035, flows of over 2 GW mainly from the Southern to the Northern zone are observed;
- Taking into account the planned unification of the Western Zone with the North-South ICS, exchange flows between the North-South ICS capacity and the Western Zone in the amount of ≈± 0.6 GW are observed at certain hours;
- The amount of curtailments of WPP/SPP due to insufficient regulating capacities in the Power system of Kazakhstan is increasing and, under accepted conditions, may reach up to 1% by 2030, up to 5% by 2035%;

Figure 2. Participation of power plants of the Republic of Kazakhstan on an hourly basis, taking into account the technological capabilities of power plants

2030



2035 (including NPP)



- The introduction of large renewable energy projects unaccounted for in the Energy Balance of the Republic of Kazakhstan until 2035, without the introduction of measures to reduce curtailments on renewable energy generation, may lead to an increase in curtailments of up to 30%.
- In world practice, the following is used to reduce the volume of renewable energy curtailments:
- Energy storage devices,
- Grid transfer capabilities,
- Demand response programs,
- Increasing the regulating range of the power plant by reducing the technical minimum load,
- Regional cooperation to ensure mutual regulation.

However, in order to determine the effectiveness of the above-mentioned means within the framework of the Energy System of Kazakhstan, detailed studies and a feasibility study are required.