Scenarios for development of the electric power industry (LCGP) and the balance of electricity and capacities of Kazakhstan until 2035

Zhenis Dyusenov,
Director, Department for Development of the National Electric Grid, KEGOC JSC

Kim Inna,
Head of the Energy Systems Research Department, Energy System Researches LLP

The development of the energy industry largely determines the development of the country and should be implemented proactively, taking into account the long construction and commissioning of energy facilities. In this regard, forecasting of the development of the industry is carried out, which, depending on the goals and planning horizons, is divided into short-term, medium-term and long-term.

Short-term forecasting (1-3 years) assumes a detailed action plan for the period under review. The goal of medium–term forecasting (5-7

years) is to determine quantitative indicators and resource allocation plan. Long-term planning (more than 10 years) is carried out to make strategic decisions aimed at introducing political and technical innovations in order to better allocate resources, achieve goals and international commitments.

Thus, medium-term planning (7 years) in Kazakhstan is fixed by the Law of the Republic of Kazakhstan «On Electric Power Industry», whereby the forecast balance of capacity and electricity is compiled annually by KEGOC JSC and approved by the Ministry of Energy of the Republic of Kazakhstan. The forecast seven-year balance is compiled in accordance with the «Rules for development of forecast balances of electric energy and capacity» and allows identifying the period of onset and the size of the shortage of electricity and capacity.

The forecast balance of capacity and electricity until 2035 was carried out in accordance with the President's instructions given at an expanded meeting of the Government on January 25, 2021. The purpose of this long-term forecast is to consider options for covering the long-term shortage of capacity and electricity, taking into account the adopted energy development targets and the international obligations of the Republic of Kazakhstan on reduction of emission, and to assess the possible results of the decisions taken.

The forecast balance of capacity and electricity until 2035 was developed based on officially provided source data from relevant organizations, large consumers of electricity and government agencies, energy-producing organizations upon request:

- to the Ministry of Energy (DOE) of the Republic of Kazakhstan;
- to the Ministry of National Economy (MNE) of the Republic of Kazakhstan;
- to the Ministry of Industry and Infrastructure Development (MIID) of the Republic of Kazakhstan;
- to SWF «Samruk-Kazyna»;
- to Samruk-Energo JSC;
- to Financial Settlement Center of RE LLP;
- to power plants;
- large consumers;
- to electric grid distribution companies (EDC);
- to local executive bodies (akimats);
- to special economic zones (SEZ), etc.

Within three months (April – July 2021), total of more than 240 requests were sent, with fulfillment of 80%. The data of public organizations, NCE RK «Atameken», the election program of the Nur Otan party, etc. were taken into account.

Planning the operation of the power system includes a large number of variables and constraints; therefore, in order to find the optimal scenario of development from all possible alternatives, it is necessary to use mathematical models. Optimization models, usually, assume high requirements to computational resources, therefore, when modeling complex systems, such as energy, a reasonable determination of initial positions and assumptions is required.

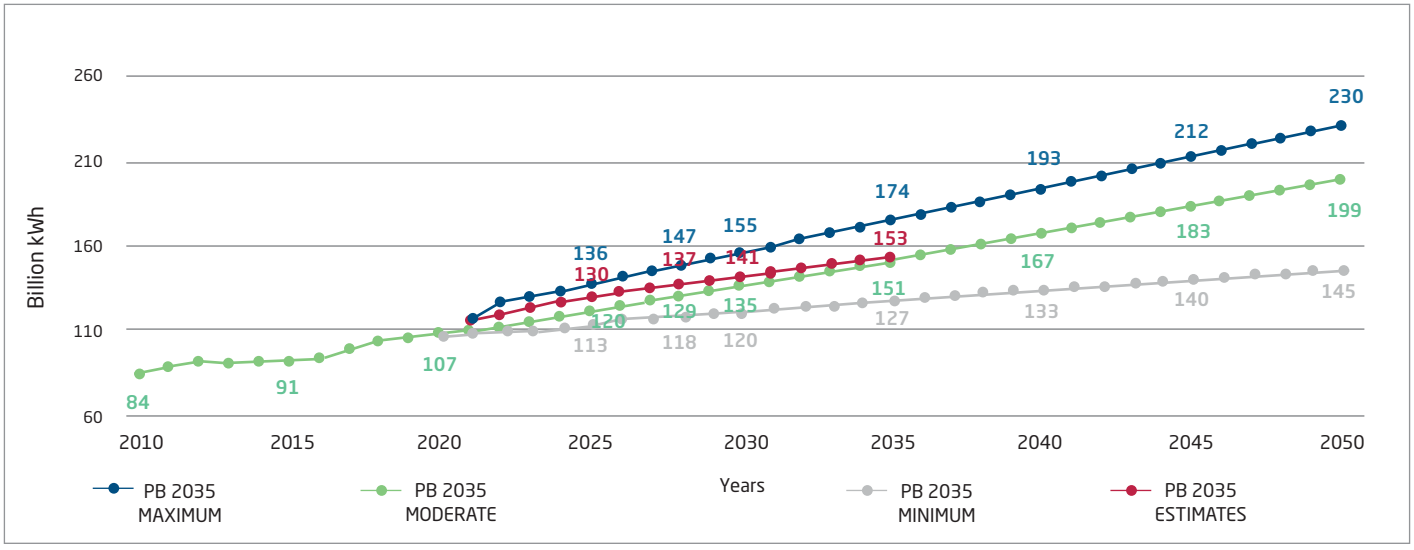
The forecast balance of capacity and electricity until 2035 was developed using the ORDENA software, which allows performing long-term forecasting of energy development at the lowest cost when the specified restrictions are met. The block diagram of modeling scenarios for the development of the power system is shown in the figure below.

This article will present the results of the simulation of scenarios for the development of the electric power industry of Kazakhstan (LCGP) and the resulting balance of electricity and capacity of the National Grid of Kazakhstan until 2035.

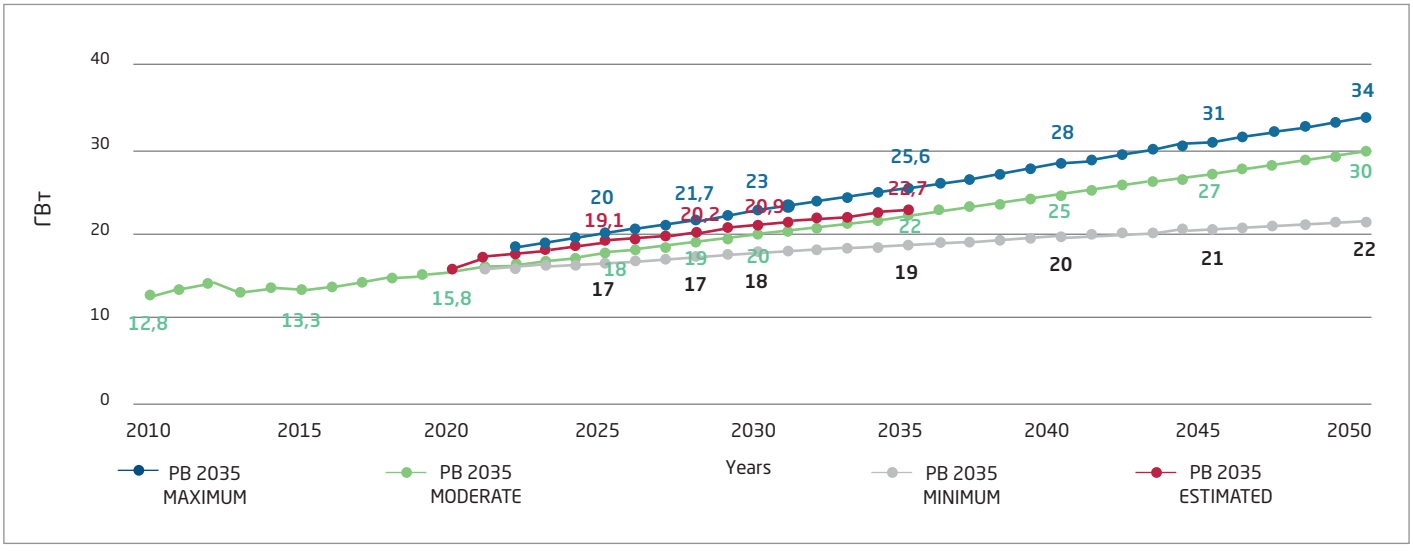
Traditionally, the development of balance begins with forecast of electricity consumption and electrical loads in the long-term, which was carried out according to three scenarios, while the 'Estimated scenario' was taken as the basis according to which the electricity consumption in National Grid of the Republic of Kazakhstan would be 137 TWh in 2028 and 153 TWh in 2035. The total electric load of the National Grid of the Republic of Kazakhstan is projected to be 20.2 GW in 2028 and 22.7 GW in 2035, respectively.

In addition, based on the results of the review of the Concept and Doctrine of Low-Carbon Development (CDLCD), when analyzing the sensitivity of the results of optimizing the lean cost generation plan (LCGP), the Maximum scenario was additionally considered, providing active development of agriculture, electric transport, information technology (data processing centers) and a significant increase in the specific rates of municipal consumption.

ELECTRICITY CONSUMPTION IN THE RK

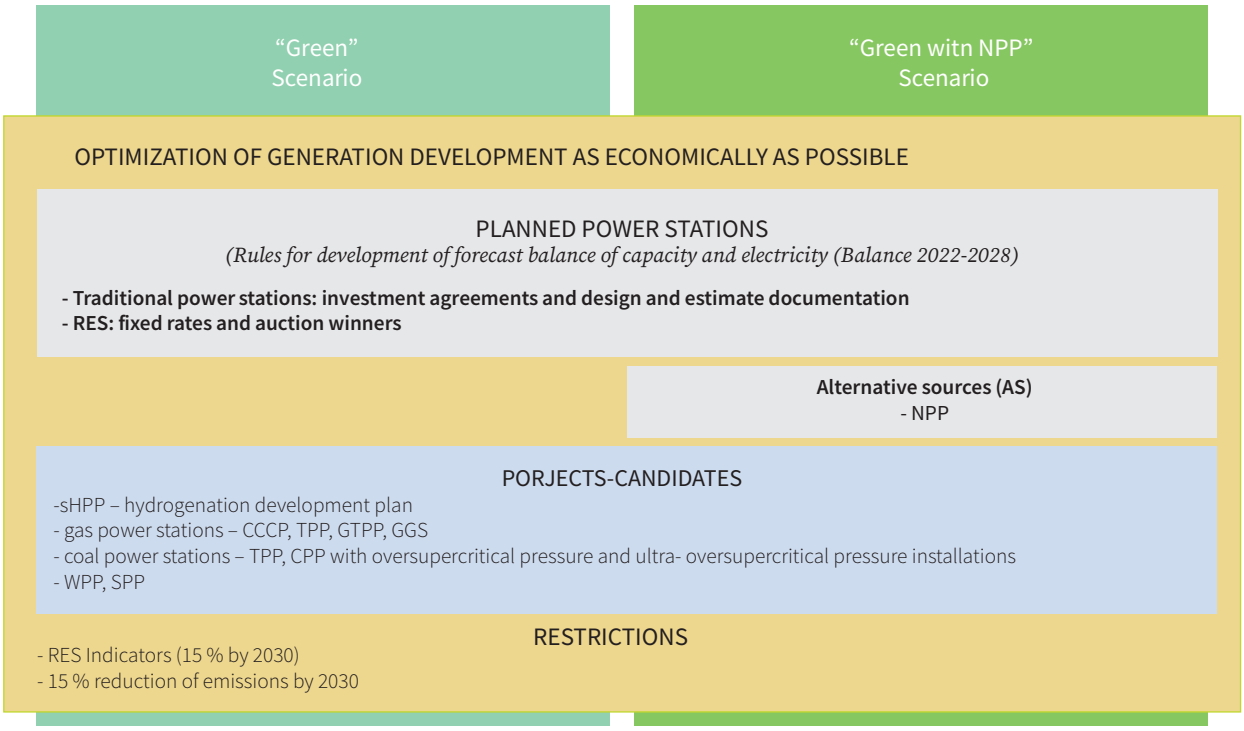


LEVELS OF MAXIMAL POWER LOADS IN THE RK

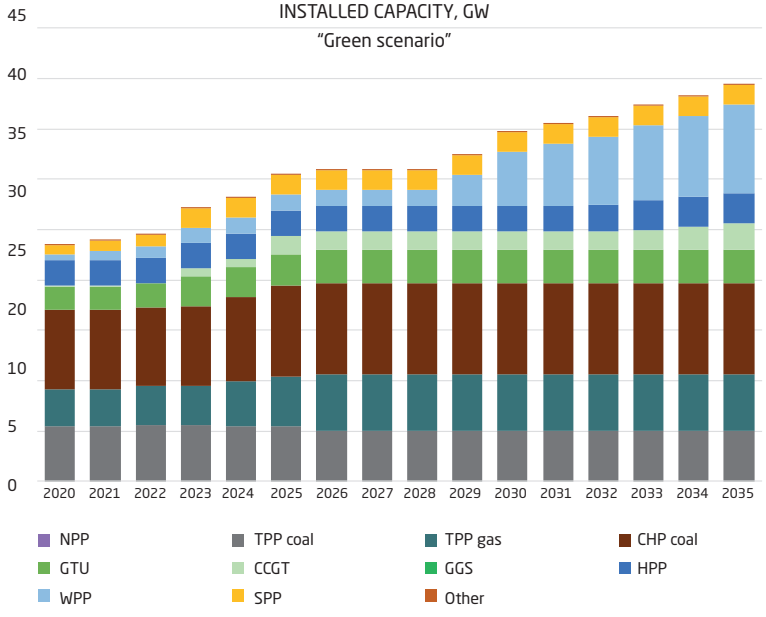


According to the existing condition (2020 report), the total electricity consumption for the National Grid of the Republic of Kazakhstan amounted to 107 billion kWh, and the peak load was 15,8 GW.

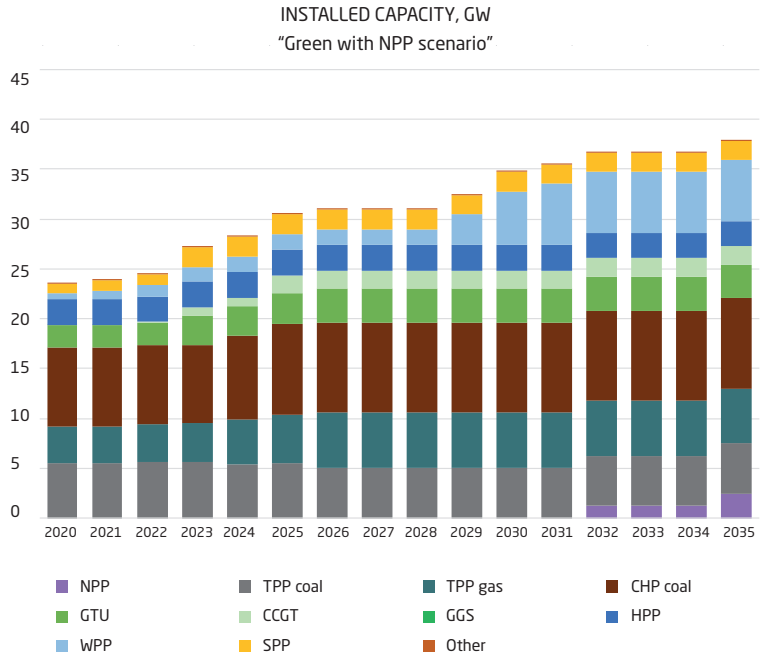
Modeling was performed for two scenarios of generation development: «Green» and «Green with NPP».



The following are the results of modeling the optimization problem of covering the electricity and capacity needs of the National Grid of the Republic of Kazakhstan until 2035 with minimal system costs, as well as taking into account the boundary conditions for CO_2 emissions, the availability and cost of fuel, CAPEX and OPEX for various generating technologies, the topology of the power system and reliability requirements.



Name	Introduction of generating capacities		
	2028	2035	Total for RK before 2035
NPP	0	0	0
TPP coal	301	0	301
CHP coal	1 136	0	1 136
CCGT	1 811	840	2 651
TPPgas	2 219	0	2 219
GTU	1 088	0	1 088
GGS	0	0	0
HPP	0	409	409
sHPP	1 931	105	2 036
SPP	1 003	0	1 003
WPP	996	7 241	8 237
TPP masut	0	0	0
BioEP	0	111	111
TOTAL	10 485	8 706	19 191



Name	Introduction of generating capacities		
	2028	2035	Total for RK before 2035
NPP	0	2 400	2 400
TPP coal	301	0	301
CHP coal	1 136	0	1 136
CCGT	1 811	0	1 811
TPPgas	2 219	0	2 219
GTU	1 088	0	1 088
GGS	0	0	0
HPP	0	55	55
sHPP	1 931	105	2 036
SPP	1 003	0	1 003
WPP	996	4 476	5 472
TPP masut	0	0	0
BioEP	0	111	111
TOTAL	10 485	7 147	17 632

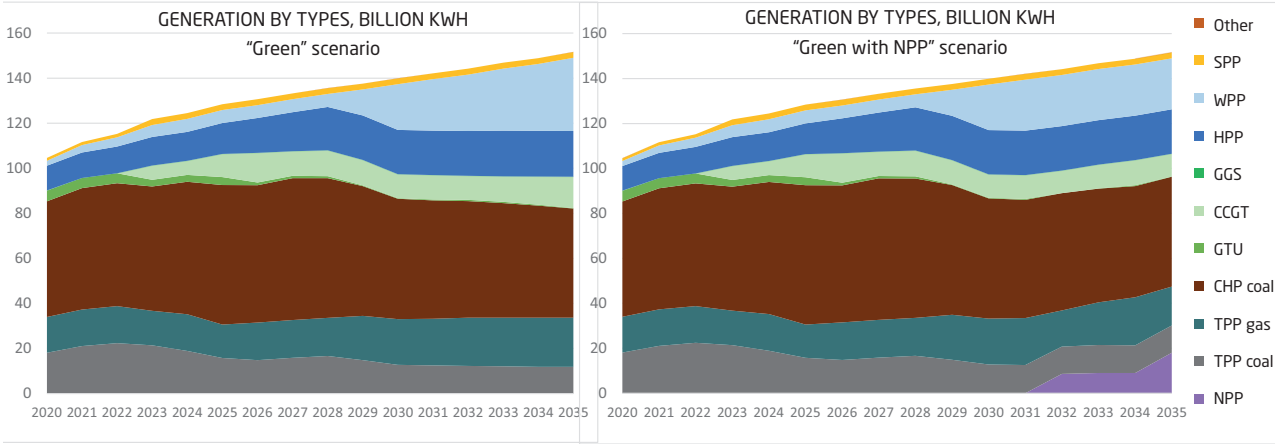
In terms of the size and structure of generating capacities, in general, in the Republic of Kazakhstan until 2035, it is expected to increase the installed capacity by ≈ 19.2 GW under the «Green» scenario, and ≈ 17.6 GW under the «Green with NPP» scenario.

According to the «Green» scenario, the main inputs account for gas generating sources (CCGT – 2.7 GW + CHP gaz – 2.2 GW + GTI – 1.1 GW = 6.0 GW), WPP (= 8.2 GW) and SPP (= 1.0 GW), as well as hydraulic power plants (HPP - 0.4 GW + MHPP – 2.0 GW = 2.4 GW).

According to the «Green with NPP» scenario, in comparison with the «Green» scenario, the commissioning of nuclear power plants in the period 2032-2035 (= 2.4 GW) leads to a decrease in inputs to the CCGT by -0.9 GW (= 1.8 GW), and to the wind power plant by -2.7 GW (= 5.5 GW). Inputs at hydraulic power plants are also reduced by -0.35 GW (HPP – 0.05 GW + MHPP – 2.0 GW = 2.1 GW).

In terms of electricity generation at power stations of the Republic of Kazakhstan in 2035:

- According to the «Green» scenario, the share of coal–fired power plants will decrease to 40%, gas-fired power plants will increase to 24%, hydroelectric power plants, including small hydroelectric power plants, will amount to 13%, wind power plants and SPP – 23%. The total expected gas consumption will be 7.5 billion m^3.
- According to the «Green with NPP» scenario, in comparison with the «Green» scenario, the share of electricity generation at the NPP will be 12%, gas – 18%, WPP and SPP will be 17%. At the same time, the total expected gas consumption will be 6 billion m^3.



Name	"Green" scenario	"Green with NPP" scenario
Generation in 2035, billion kWh	152	152
PP coal	40%	40%
PP gas	24%	18%
NPP	0%	12%
HPP	7%	7%
sHPP	6%	6%
WPP	21%	15%
SPP	2%	2%
Gas consumption in 2035, billion m^2	7,5	6,0

CO_2 emissions have been declining since 2028, reaching the unconditional targets under the Paris Agreement –15% in 2030 and continuing to decline. At the same time, at the level of 2035, the share of emissions from coal–fired power plants is 90–91%, gas-fired power plants – 9–10%.

By 2035, ICUF at the CCGT is increasing, at the GTI it is decreasing, which indicates the transition of the GTI to work in the peak of load coverage schedule. At coal-fired thermal power plants and CP, the ICUF also reduces due to the requirements for limiting CO_2 emissions.

Emissions are reduced by reducing ICUF of coal-fired power plants, increasing the share of renewable energy and gas generation in the «Green» scenario, as well as by introducing a nuclear power source in the «Green with NPP» scenario.

Name		"Green" scenario	"Green with NPP" scenario
Emissions, mln. т CO_2		89	89
	PP coal PP gas	90% 10%	91% 9%
Total reduced system costs, billion		32,7	37,8
	fixed	11,5	11,4
	variable	2,6	2,6
	cost of fuel	5,6	5,8
	capital expenditures	13,0	18,0

The total inputs of generating capacities for the period up to 2035 amount to 17.6 GW, and the increase in installed capacity is 16.6 GW (the difference is due to the fact that according to the «Rules ...» the outputs of the existing generation are also taken into account).

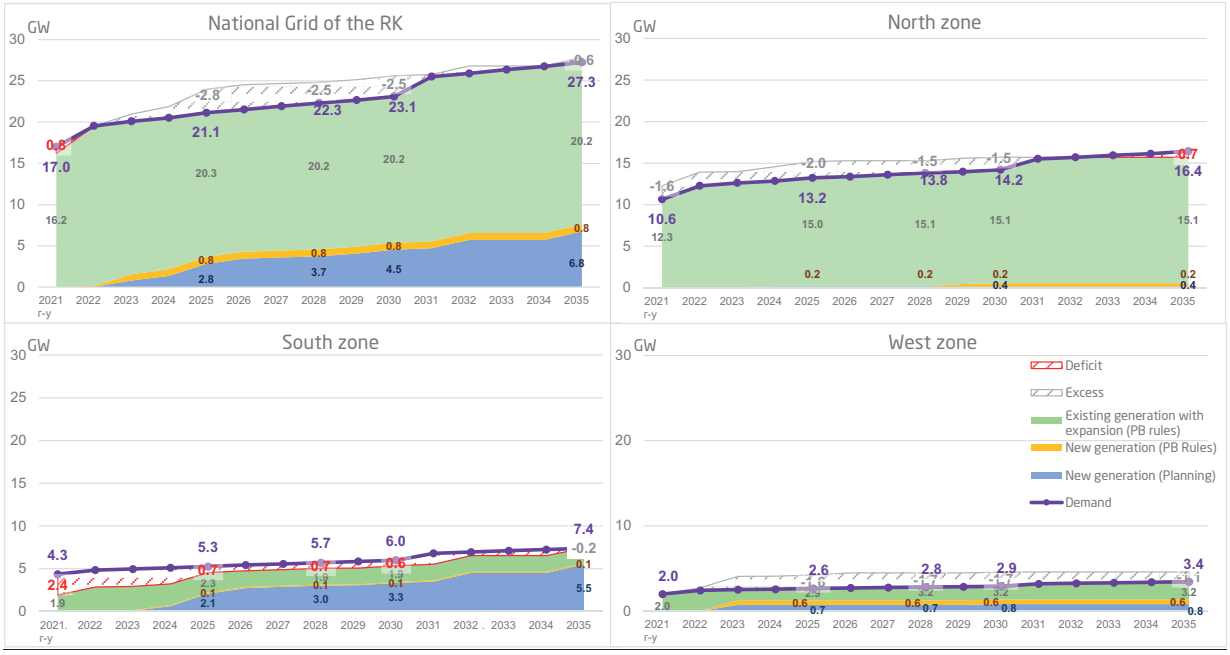
The balances of electricity and capacity for the period up to 2035, taking into account the planned optimization of the development of generation under the «Green with NPP» scenario and without it, are shown in the figure below.

It should be noted that in general, taking into account the planned optimization of the development of generation, the National Grid of Kazakhstan is self-balancing in terms of electricity.

Without taking it into account, an increasing shortage of electricity and capacity is expected, which in 2030/2035 may exceed 40/60 TWh and 3/7 GW, respectively.

ELECTRICITY BALANCE

CAPACITY BALANCE



The electricity balance for 2035 in the Northern and Western zones is formed with a deficit of 14,7 TWh and 9,0 TWh, respectively, in the Southern zone – with an excess of 22,4 TWh due to a decrease in production at coal-fired thermal power plants and thermal power plants and an increase in production at nuclear power plants, gas-fired thermal power plants and renewable energy sources, which are currently expanding in the Southern zone. The capacity deficit of the Southern Zone is gradually decreasing from 2.0 GW in 2022, and in 2035 the balance will be in excess of 0.2 GW. In the Northern Zone, the excess capacity is gradually decreasing, and starting from 2032 the balance becomes deficient to 0.8 GW in 2035. In the Western Zone, an excess capacity of up to 1.8 GW is predicted for the entire period. To cover the projected deficits in the North–South association, it is necessary to unite with Western Kazakhstan.

The main measures aimed at ensuring coverage of the projected demand for capacity and electricity in the National Grid of Kazakhstan include:

In the short term:

- Participation of ZHGRES in full-block mode.
- Organization of electricity import.
- Introduction of financial responsibility to cover deviations between the projected and actual capacity of renewable energy facilities, as one of the incentives for the installation of energy storage systems.
- The introduction of balancing market in real mode and the return of tariffs differentiated by the hours of the day to the practice for wholesale and retail consumers as the initial stage of the implementation of demand management program (tariff increases during peak hours and decreases during the hours of failure, especially relevant for the Southern zone).

Medium -term measures include:

- Implementation of all planned reconstruction, expansion and modernization projects, including the commissioning of units at EGRES 1 (500 MW) and EGRES 2 (636 MW).
- Implementation of plans for the development of gas generation (Turkestan CCGT 1000 MW, Shymkent CCGT CHPP 450 MW, Kyzylorda CCGT 250 MW, Almaty CCGT CHPP 1-3).
- Implementation of plans for the development of hydraulic power industry.
- Development of renewable energy projects and energy storage systems.
- Construction of nuclear power plants.