ASTANA IT UNIVERSITY

Feasibility Analysis on Renewable Energy Power Plant Development in Kazakhstan

Dr. Nurkhat Zhakiyev

nurkhat.zhakiyev@astanait.edu.kz

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General concept

❖Objectives:

Integrated hybrid modeling tool of the energy system

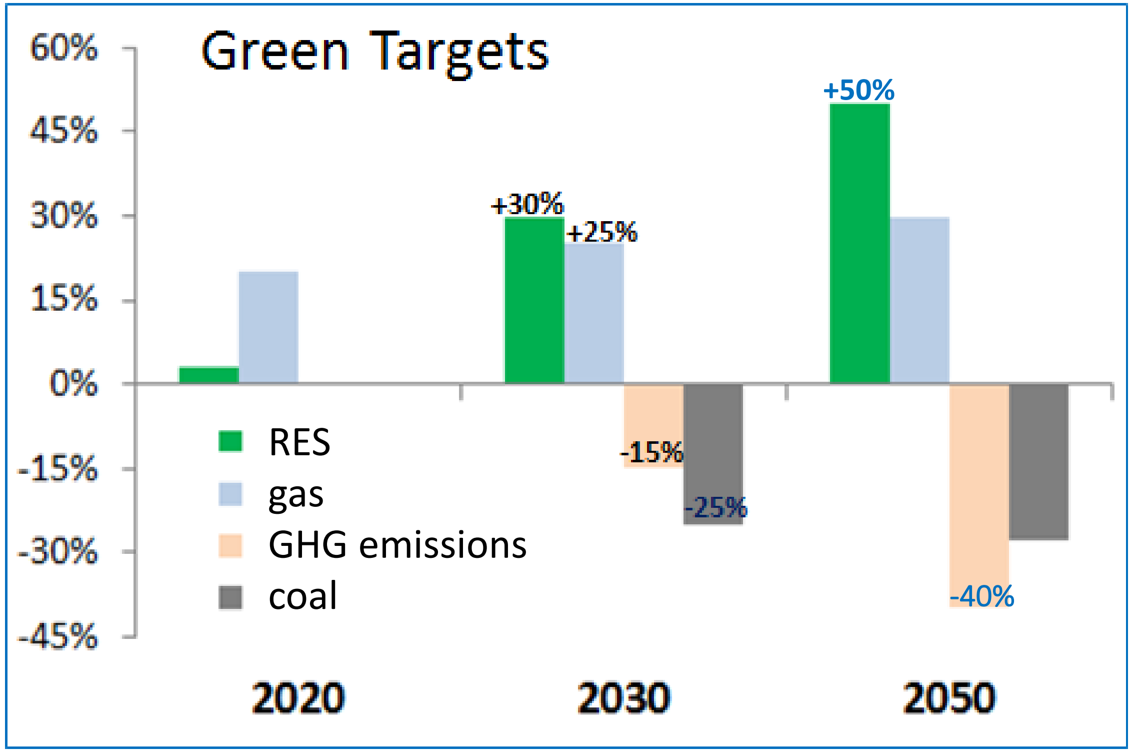
- long-term planning model of the energy system
- operational model of the electric power system
- Scenario Analyses

Roadmap of RE deployment 2030/2050

- optimal allocation and performance parameters
- reliability
- economic feasibility
- environmental friendliness

Scientific novelty and significance

- The Paris Agreement
  - Updating the commitment to reduce GHG emissions by NDC
  - Development of new Roadmaps for each of the next 5 years
- The strategy “Kazakhstan-2050”
  - 50% of the energy consumption from green and alternative energy
  - Low Carbon Development Strategy 2060



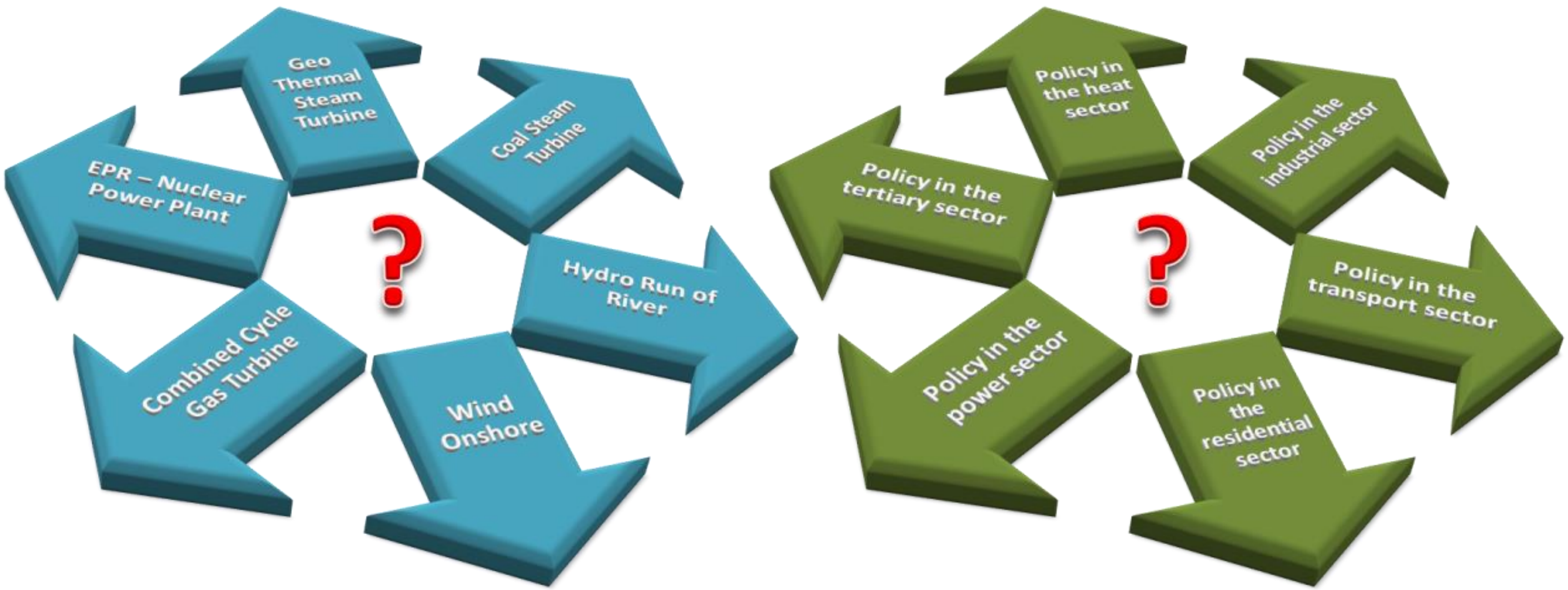
Scientific novelty and significance

RES	Conventional coal power plants
Intermittent, unstable, specific for location and predictable only to a limited extent.	Limited rapid start-up and hot standby capabilities
Variability and uncertainty in planning and operation, less reliability	Additional operational costs due to RESs

❖ It is necessary to consider all the economic and technical consequences of RESs introduction in RE roadmap

Scientific novelty and significance

- Energy System Model: a simplified mathematical description of energy flows and technologies of a system, able to investigate different energy paths in a quantitative manner.



Scientific novelty and significance

<table>
<tr><th>Long-term energy system models</th><th>Operational power models</th></tr>
<tr><td colspan="2">Advantages</td></tr>
<tr><td rowspan="2">investments, operation modes, production & consumption and associated prices</td><td>detailed technical constraints</td></tr>
<tr><td>time resolution in the range of 15 minutes to one hour</td></tr>
<tr><td colspan="2">Disadvantages</td></tr>
<tr><td rowspan="2">unable to consider short-term changes and limitations associated with increase of RESs</td><td>unable to do long-term investment decisions</td></tr>
<tr><td>time horizon is limited from one day to one year</td></tr>
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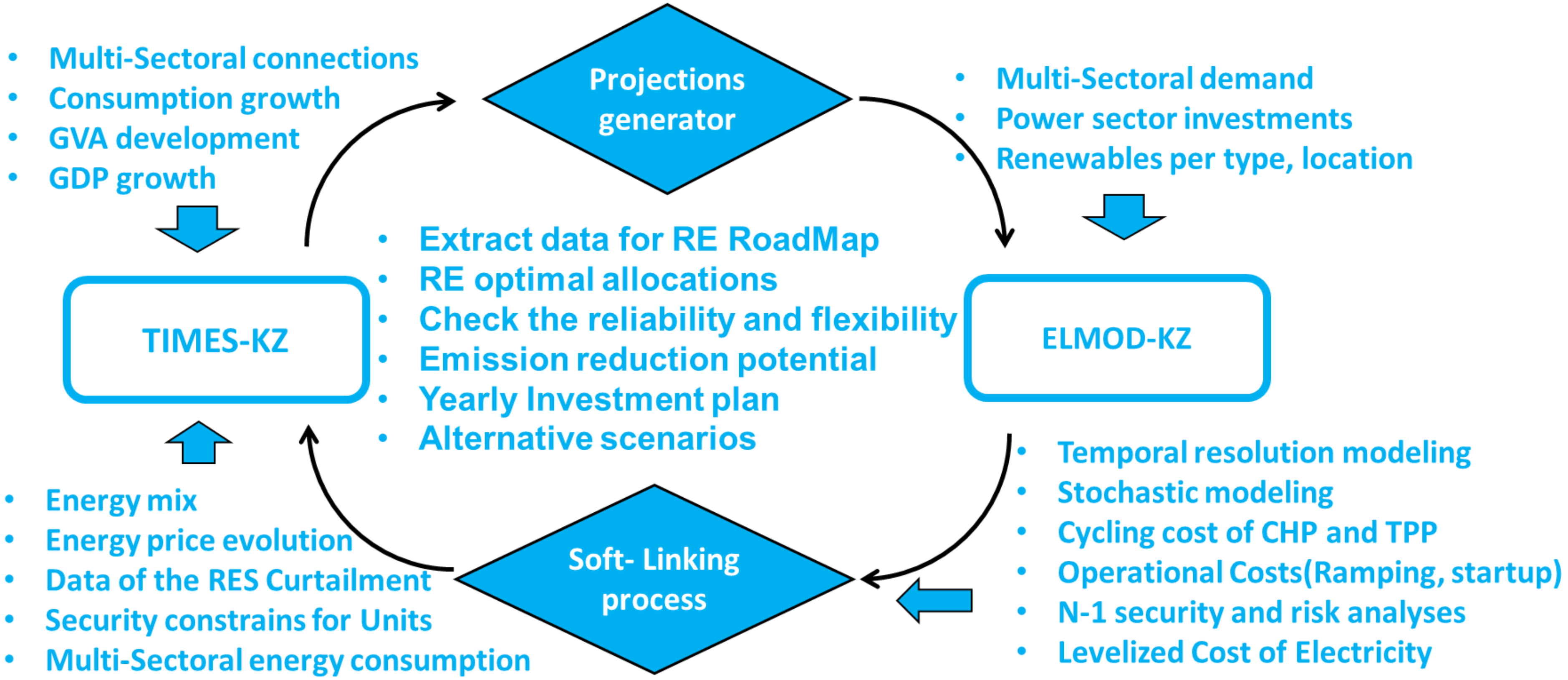
Research methods and Tools

❖Linking schemes



Research methods and Tools

- ❖Long-term energy system models - TIMES (The Integrated MARKAL-EFOM System)
  - Linear programming bottom-up energy models
  - Integrated modeling of the entire energy system
  - Prospective analysis on a long-term horizon (20- 50 yrs)
  - Demand driven (exogenous) in physical units
    - Price-elasticities for end-use demands (optional)
    - Partial and dynamic equilibrium (perfect market)
  - Optimal technology selection
  - Environmental constraints (GHG emission limits)
  - Energy and emission permits trading
  - Objective-function: Maximization of the net social surplus (mono-objective)

Research methods: TIMES

- Long-term energy system models - TIMES (The Integrated MARKAL-EFOM System)

Input data

- Representation of the existing system (capacities and flows)
- Assumptions about final demand for energy products over time
- Techno-economic indicators of future technologies
- Country-specific technical and natural limitations
- Set of policies / measures / projects

TIMES

- Provides energy services at the lowest cost while making decisions about investments and equipment operation, primary energy supply and energy trading

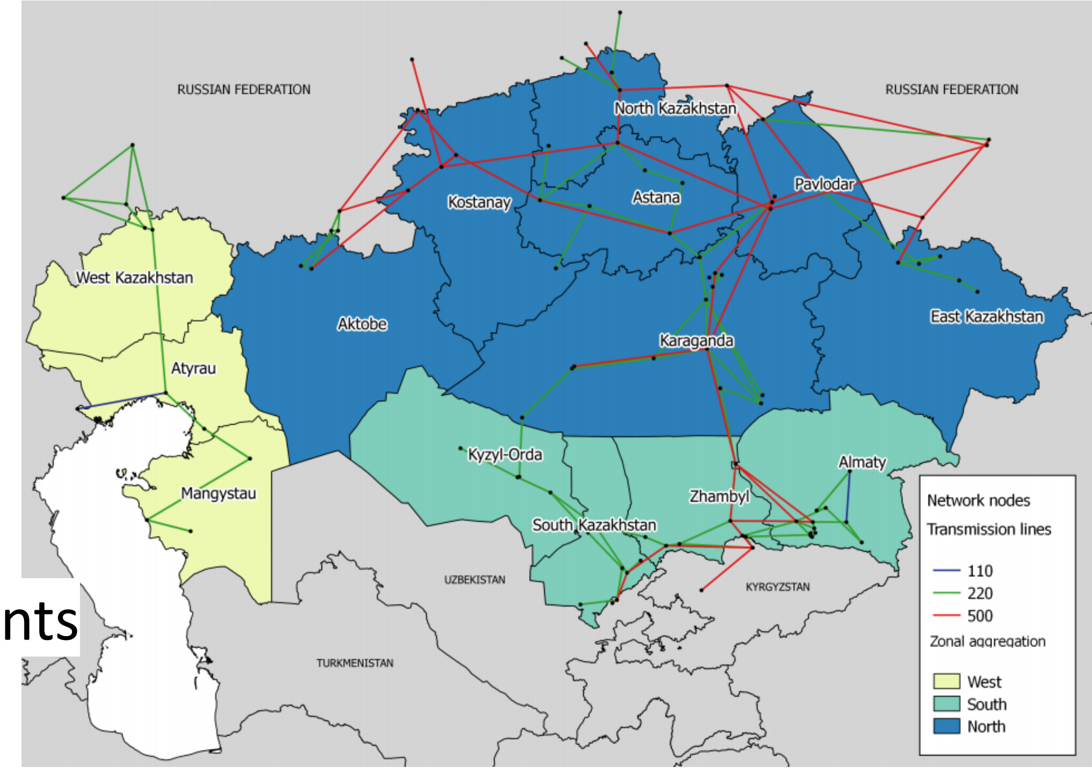
Results

- Investment in technology (costs and capacities)
- Energy flows into and out of processes
- Losses
- GHG emissions

Research methods: LAC-OPF + Unit Commitment

❖Operational Power Model

- DC Load Flow - Optimal Power Flow (DCLF-OPF)
- Collected data by nodes and in hourly resolution
- Nodal–zonal prices - Tariffs for consumers
- the OpenMode initiative (PyPSA)
- Literature Review of the Power Market designs:
- Comparative analyzes
- Stochastic behavior of Solar and Wind power plants
- Risk analysis with a large share of RES
- Criteria check for N-1 network security



Research methods: LAC-OPF

Data input

Electricity demand (residential and industry)

Installed capacity of power plants

Transmission data (lines of four levels of voltage – 1150, 500, 220, 110 kV)

Fuel prices

Solar insolation and wind speed

Objective function
Minimization of total cost including: investment cost for RES, storages new lines; O&M and ramping cost; marginal cost of electricity and CO2 emissions cost

Generation constraints
Generation constraints for each block of conventional and renewable power stations

Energy balance
Generation has to be equal to demand in every hour

Transportation
Hourly flows between nodes should not exceed the line capacities

Output

Power generation and power generation capacity composition

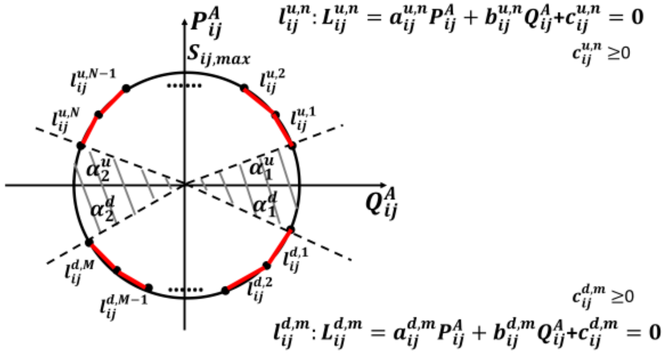
Decisions on plants construction, decomposition and retrofit

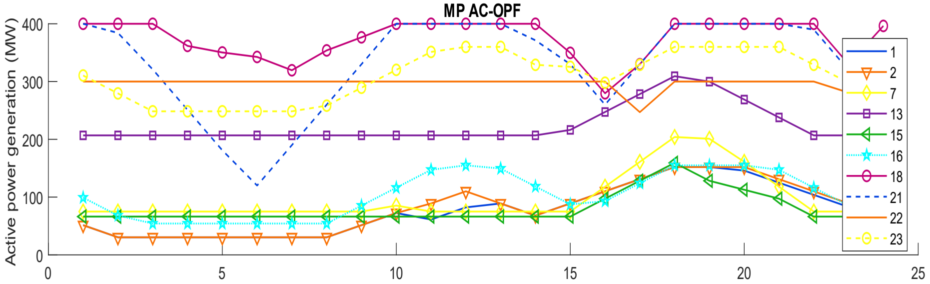
CO2 emissions

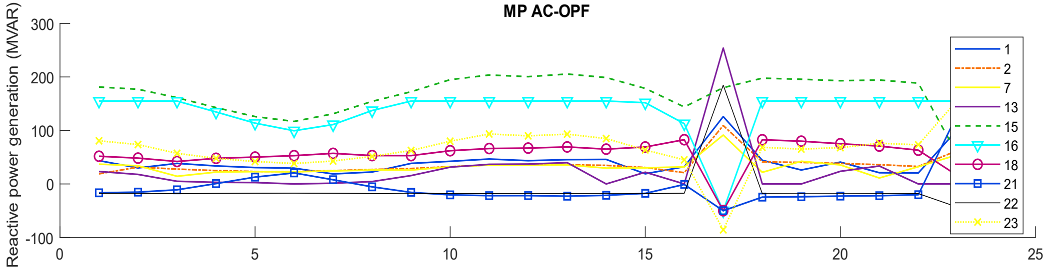
Total cost and cost composition

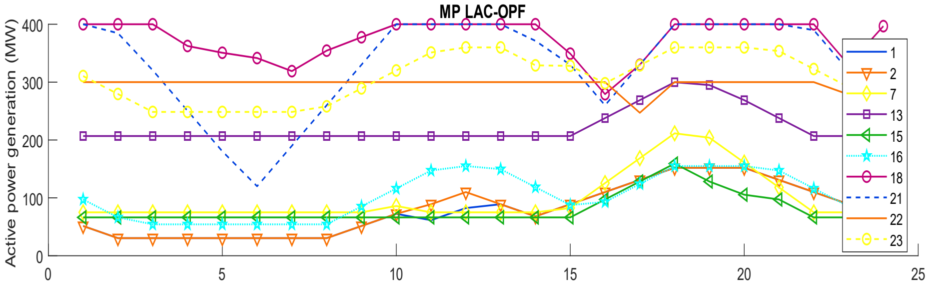
LAC-OPF approach

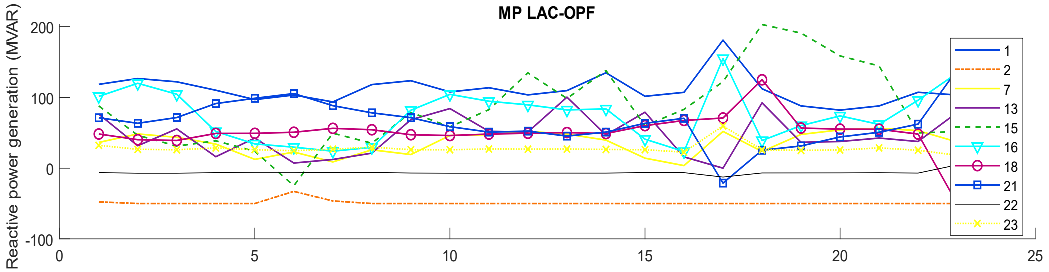
Modeling of 24-nodal IEEE RTS system
in GAMS for linearizing AC









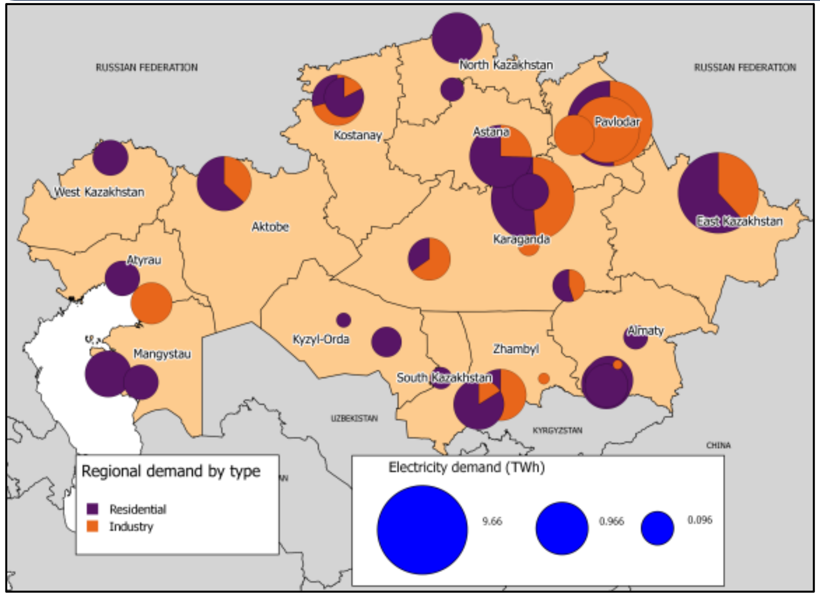


Generation of active power by power plants

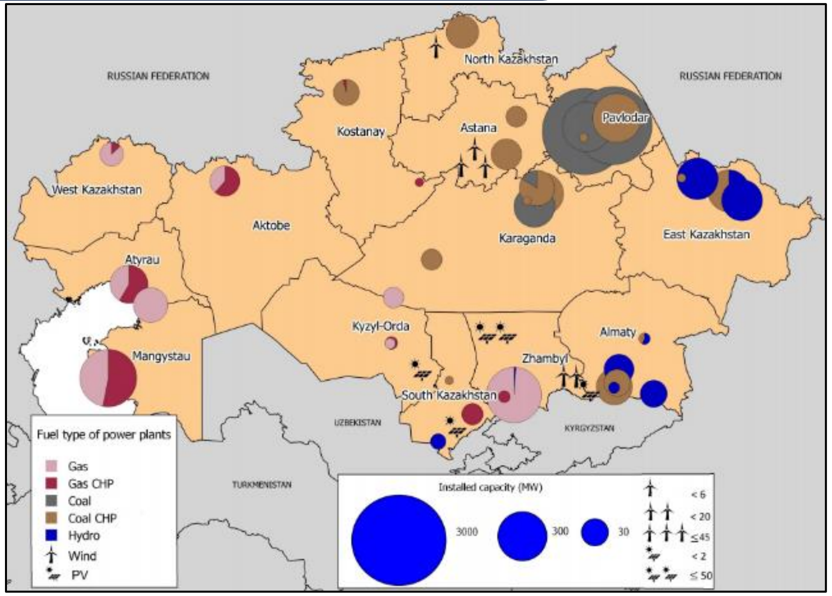
Generation of reactive power by power plants

Demand and supply
Lines utilization

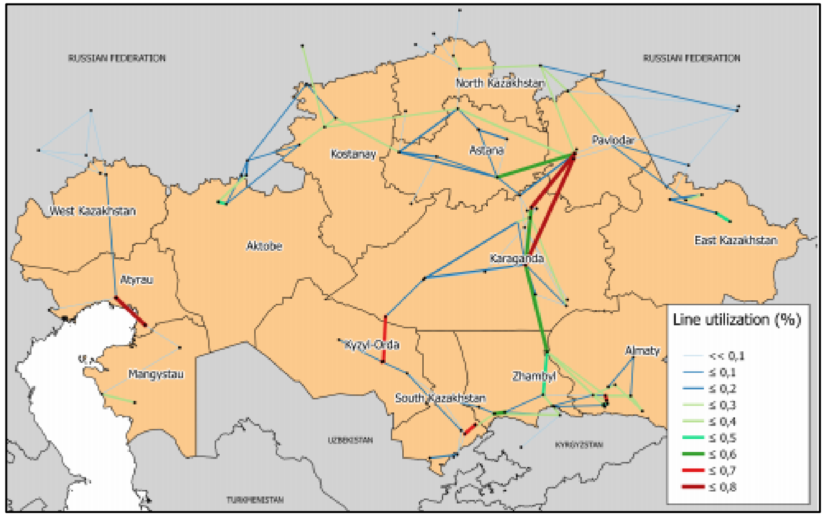
Demand by region



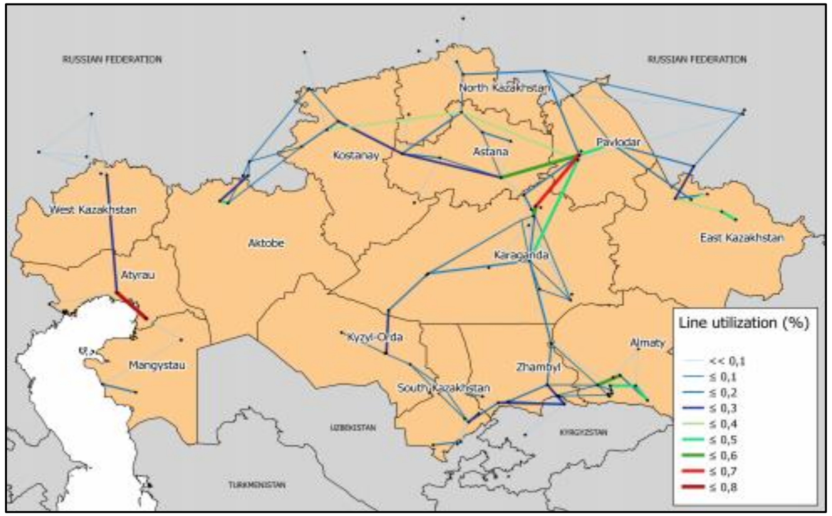
Supply by region



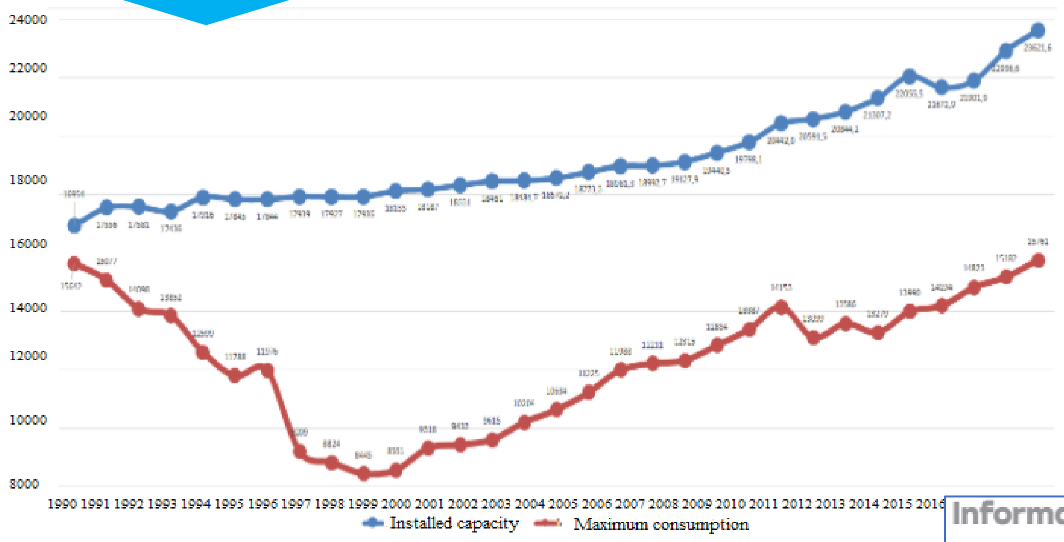
Line utilization. Winter.



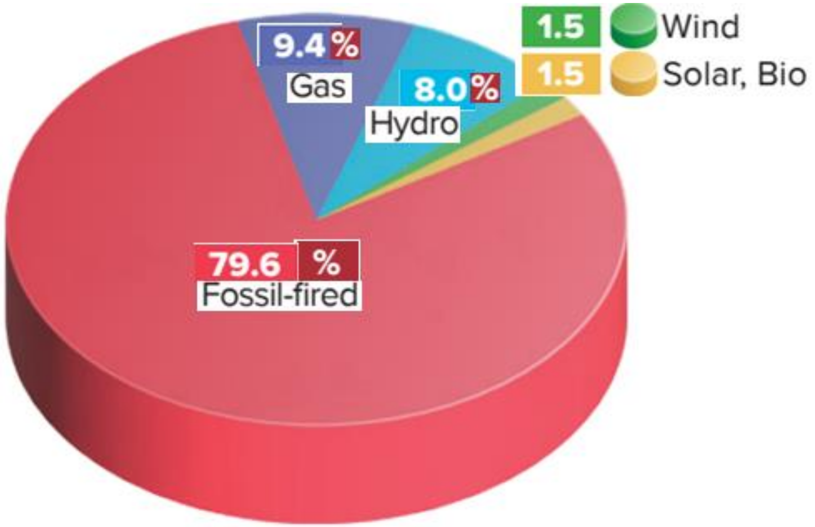
Line utilization. Summer.

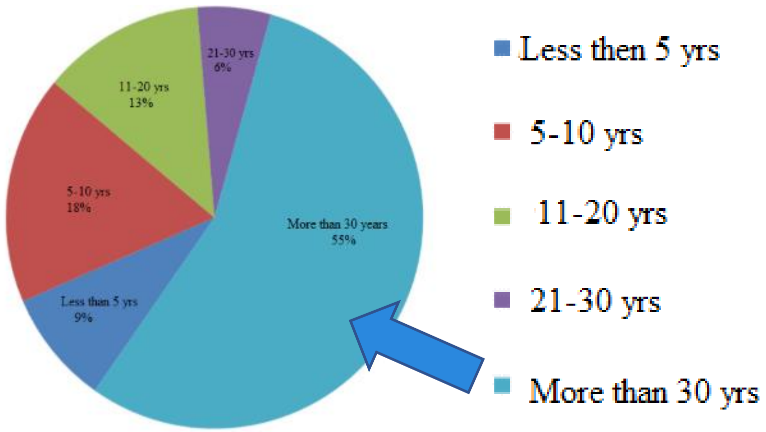


Energy Sector of Kazakhstan



Dynamics of changes in the total installed capacity of power plants and the maximum power consumption in KZ





Age of generating equipment of thermal power plants of the Republic of Kazakhstan

Information on RES electricity production in 2021

Parameters	Units	2021
Installed capacity including:	**MW**	**2,010.32**
wind power plants	MW	683.95
small hydropower plants	MW	280.98
solar power plants	MW	1,037.61
bio power plants	MW	7.82
Electricity generation including:	**million kWh**	**4,220.29**
wind power plants	million kWh	1,776.41
small hydropower plants	million kWh	799.74
solar power plants	million kWh	1,641.09
bio power plants	million kWh	3.04

	Generation, million kWh
Thermal power plants total	91,164.2
steam turbines	
▪ pulverized coal	78,981.2
▪ on gas and fuel oil	12,183.0
gas turbines	10,701.8
Hydro power plants	9,184.9
Wind farms	1,758.0
Solar power plants	1,636.5
Biogas plants	2.5

114.4 billion kWh — **Total**

Kazakhstan Renewables in 2022

130 objects of RES with total installed capcity 2388 MW

SolarPP
1149 МВт
45 объектов

HydroPP
280 МВт
37 объектов

WindPP
957,5 МВт
45 объектов

BioGasPP
1,82 МВт
3 объектов

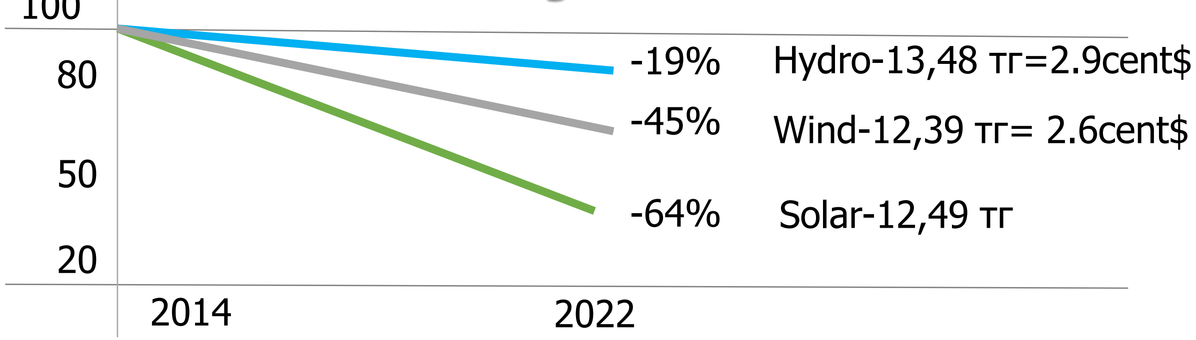
*были исключены нетто-потребители

Auction results (2018 -2022 гг.)

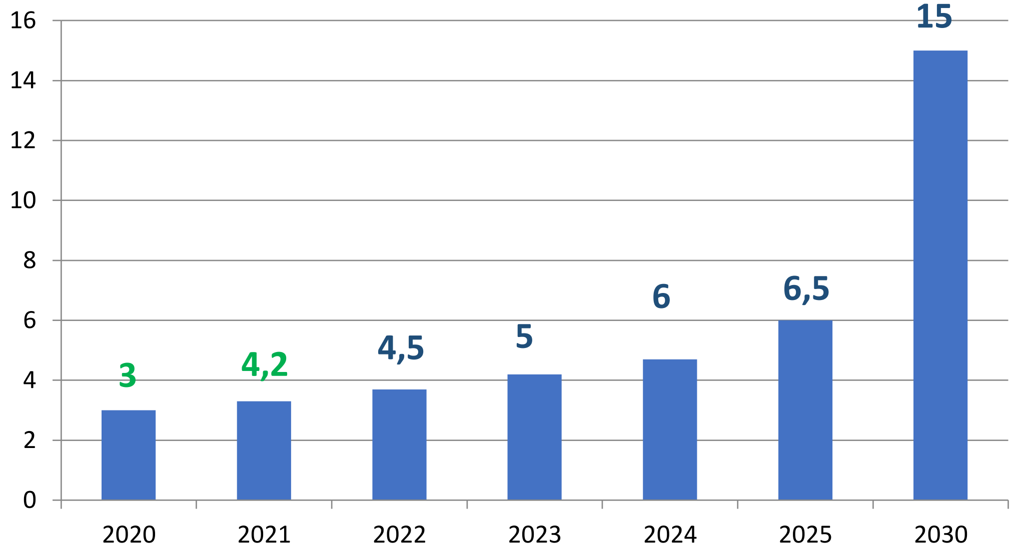
permissions2400 МВт

232 company from 13 country

Decreasing tariffs for RES



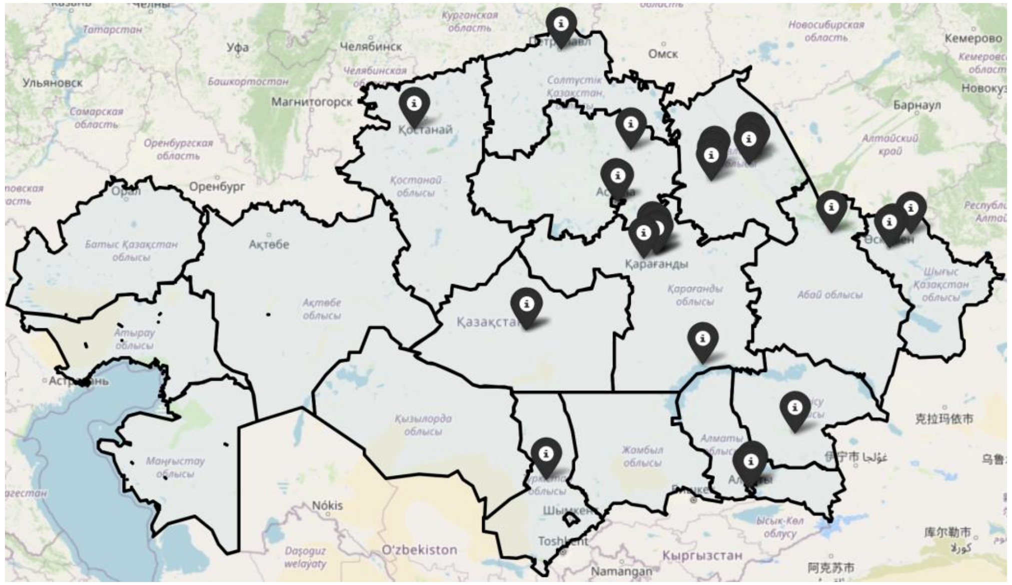
Доля ВИЭ в общем объеме производства электроэнергии, %



Итоги 2022 года

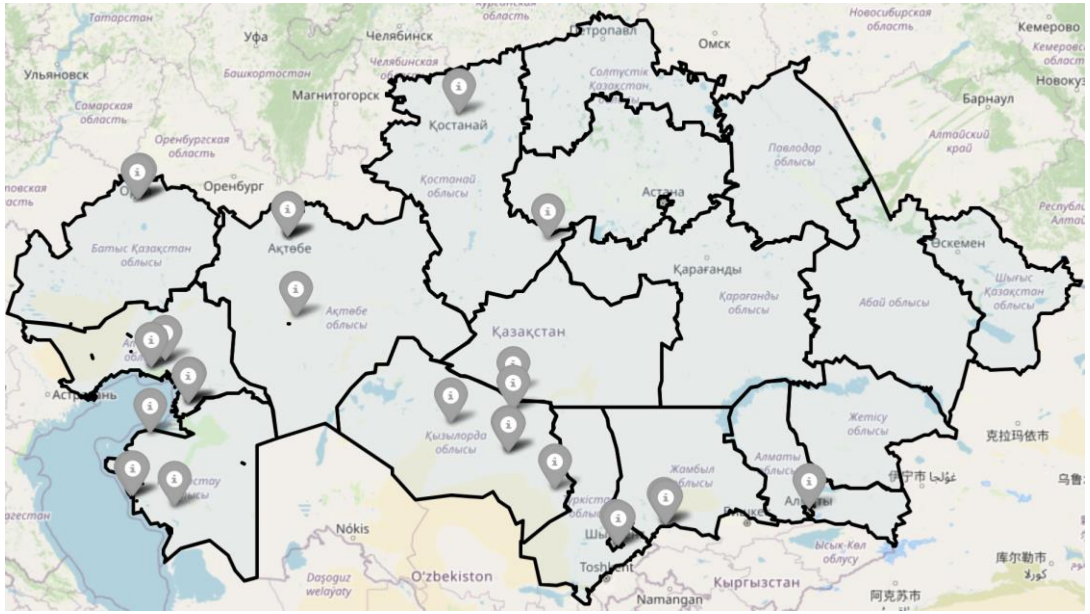
- Введено в эксплуатацию **12** объектов ВИЭ мощностью **385,4** МВт;
- Общая сумма инвестиции составила **180** млрд. тенге.
- На этих **12 объектах** создано **158** постоянных рабочих мест;
- Генерация по итогам составит свыше **4,5 млрд.кВтч.**

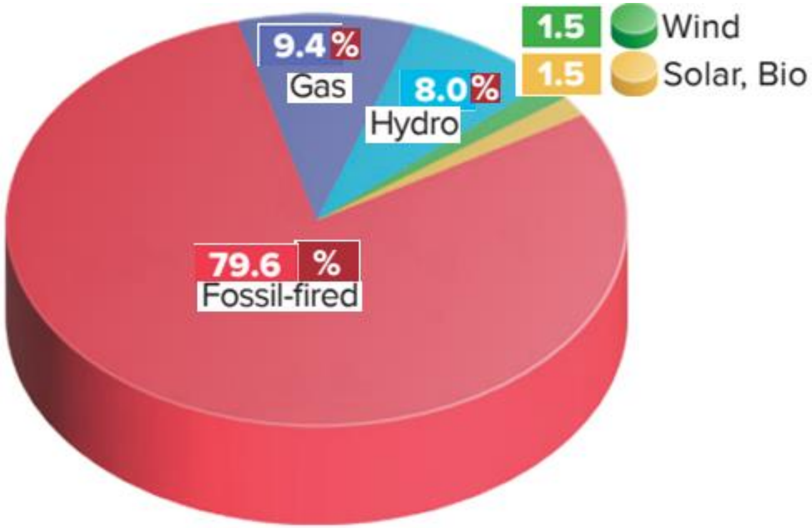
Current powerplants in Kazakhstan



Coal

Gas





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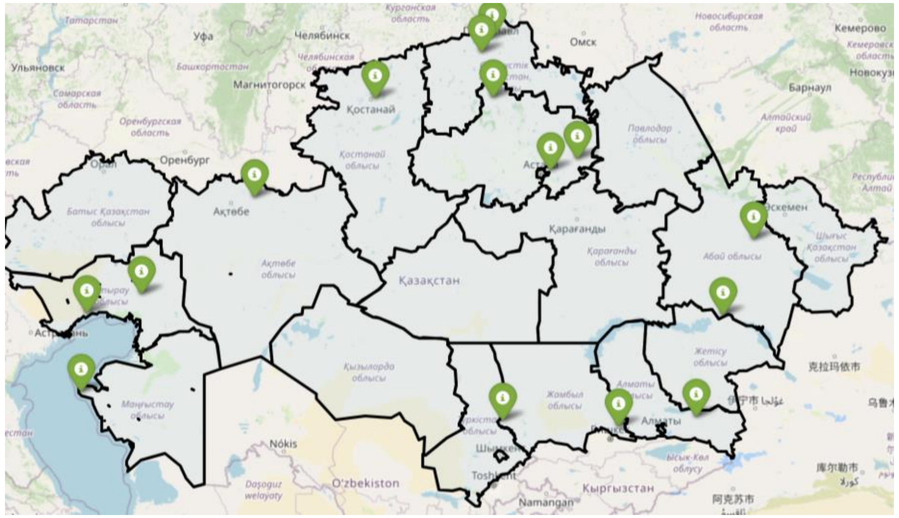
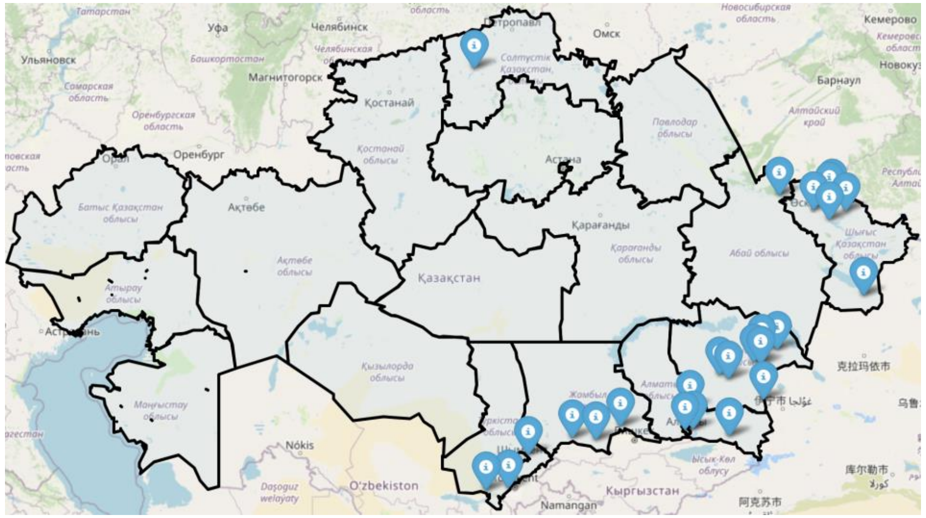


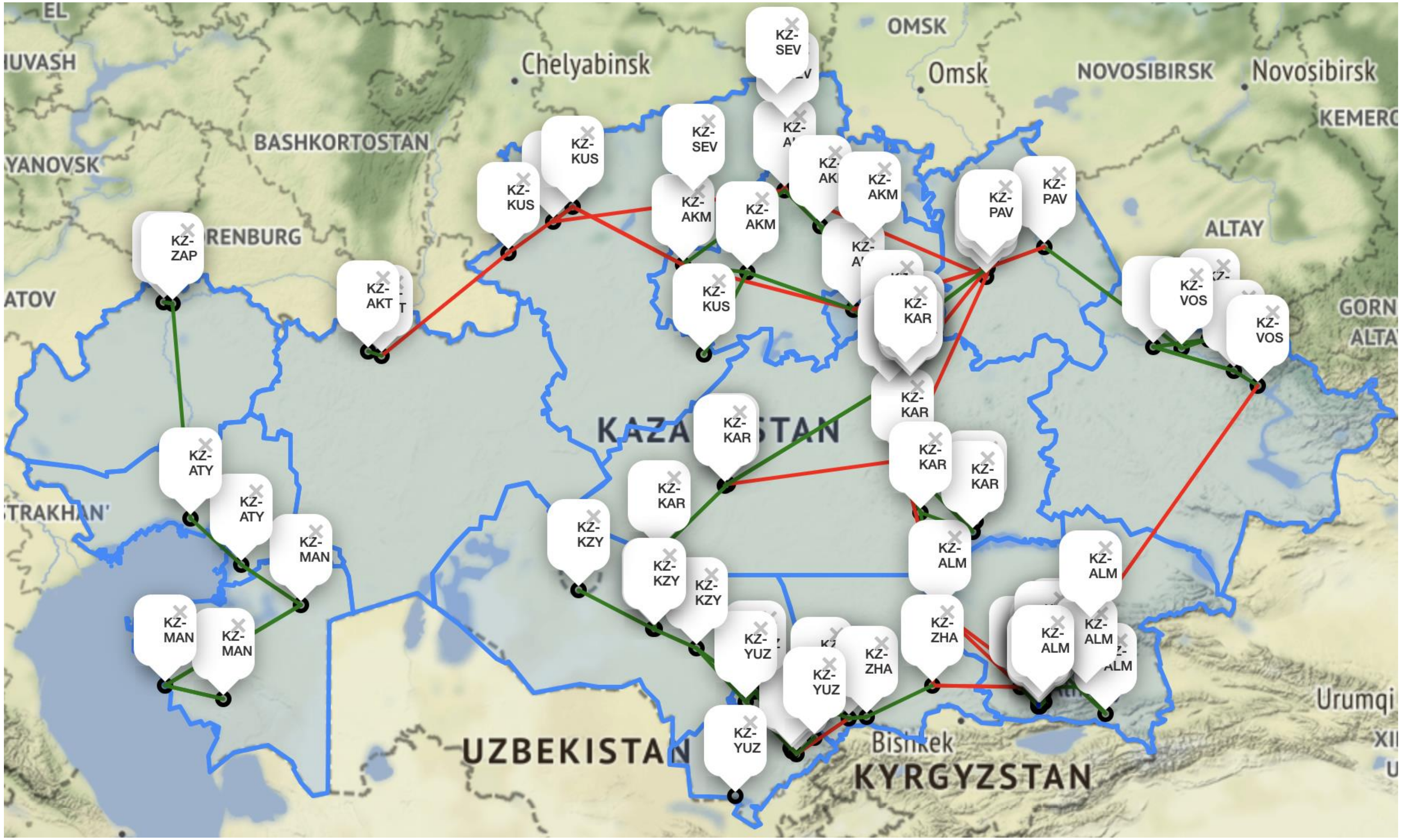
Wind



Hydro

PV

HV line network of Kazakhstan



Publications

1) Amanbek Y, Kalakova A, Zhakiyeva S, Kayisli K, **Zhakiyev N.,** Friedrich D. Distribution Locational Marginal Price Based Transactive Energy Management in Distribution Systems with Smart Prosumers—A Multi-Agent Approach. Energies. 2022; 15(7):2404. https://doi.org/10.3390/en15072404 with Impact Factor: 3.004; **CiteScore 4.5-** Q1 (in Scopus)

2) A. Zhanbolatov, S. Zhakiyeva, N. **Zhakiyev**, K. Kayisli (2022) "Blockchain-Based Decentralized Peer-to-Peer Negawatt Trading in Demand-Side Flexibility Driven Transactive Energy System" International Journal of Renewable Energy Research (IJRER), 12(3), 1475-1483. doi:10.20508/ijrer.v12i3.13195.g8530 (**Cite score-3.7,** Scopus)

3) R. Z. Caglayan, Korhan Kayisli, **Nurkhat Zhakiyev**, A. Harrouz, Ilhami Colak. A Review of Hybrid Renewable Energy Systems and MPPT Methods. International journal of Smart Grid. Vol.6, No.3, September 2022.

4) Sarsembayev, B., **Zhakiyev, N.,** Akhmetbayev, A., & Kayisli, K. (2022, June). Servomechanism based Optimal Control System Design for Maximum Power Extraction from WECS with PMSG. In 2022 10th International Conference on Smart Grid (icSmartGrid) (pp. 309-313). IEEE. https://doi.org/10.1109/icSmartGrid55722.2022.9848769

5) A. Zhanbolatov, S. Zhakiyeva, B. Azibek**, N. Zhakiyev,** K. Kayisli and D. Tursyngul, "A Multi-Carrier Energy Method for Self-Consumption Enhancement in Smart Residential Buildings," 2022 11th International Conference on Renewable Energy Research and Application (ICRERA), 2022, pp. 388-394, doi: 10.1109/ICRERA55966.2022.9922874. https://ieeexplore.ieee.org/document/9922874

6) R. Z. Caglayan, K. Kayisli, **N. Zhakiyev,** A. Harrouz and I. Colak, "A Case Study: Standalone Hybrid Renewable Energy Systems," 2022 11th International Conference on Renewable Energy Research and Application (ICRERA), 2022, pp. 284-292, doi: 10.1109/ICRERA55966.2022.9922792. https://ieeexplore.ieee.org/document/9922792

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Thank you for attention!

Contact information:

Nurkhat Zhakiyev, PhD
Department of Science and Innovation
Astana IT University
Astana, Kazakhstan
nurkhat.zhakiyev@astanait.edu.kz
nzhakiyev@gmail.com