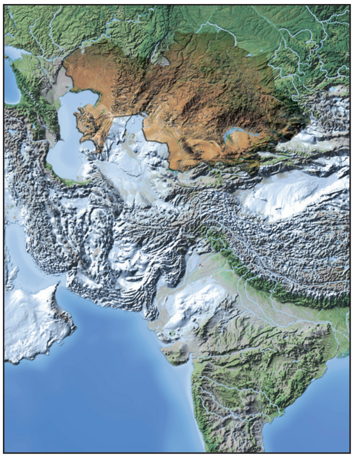


Renewable energy in Kazakhstan rises in the shadow of fossil fuels

By **Eva Karatairi**
Feature Editors:
Luis R. Rojas-Solórzano and **Aiymgul Kerimray**

Future Energy was the theme of the World Expo held in 2017 in Astana, the capital of Kazakhstan. It was chosen by the host country to highlight their wish to lead renewable development in Central Asia and source 50% of its total energy consumption from alternative and renewable energy by 2050.

The plan is ambitious: The relatively young state, which declared its independence from the USSR in 1991, is blessed—and cursed—with rich coal, oil, and gas resources, which have contributed to a high rate of economic growth. Furthermore, Kazakhstan has a 40 year reserves-to-production ratio for oil, 35 years for gas, and 150 years for coal. Therefore, electricity is generated mainly from burning fossil fuels, which is not only a relatively inexpensive form of power generation, but also the most established one for industrial and domestic use. In fact, many rural households in the poorer regions still use coal for heating purposes.

Thus, it comes as no surprise that about 75% of the country's electricity demand is still covered by coal, while renewables represent less than 1% of all power generation, excluding hydropower, which has a share of around 10% in the power mix.

The country reported CO_2 emissions (from the burning of fossil fuels and cement manufacture) at ~14 metric tons per capita in 2014, a number that placed it 18th in a list of countries where Qatar leads with 45.4 metric tons, Saudi Arabia and the United States have 19.5 and 16.6 metric tons, respectively, followed by Germany (8.9), and China (7.5). Along with an increase in greenhouse gas (GHG) emissions since 1991, economic growth has brought a steady increase in electricity consumption. As a result, the energy sector is facing big challenges: Aging coal-fired plants and inefficient power transmission networks, combined with lack of maintenance and investment, are causing losses and occasional shortages in the electricity supply.

Adopting renewable energy technologies can help the country to reduce its GHG emissions. It ensures additional generating capacity and reduces electricity imports and power network losses. Kazakhstan's landscape and climate, with windblown steppes occupying almost one-third of its northern and central territory and the sun shining between 2000 and 3000 hours each year, seem to enforce the idea that the country has a huge potential for solar and wind power.

Thus, Kazakhstan's government set out to increase the share of renewable sources in the electric mix, from the current 1%, to 3% by 2020, 30% by 2030, and 50% by 2050, according to the "Kazakhstan Strategy—2050" that was introduced in 2012. This year, the ministry of energy stated that ~114 MW from alternative sources was produced in 2017, which was 22% more than in the previous year. The plan for 2018 is ~310 MW.

To achieve its short- and long-term goals, Kazakhstan will need a lot more than wind and sun. For example, Germany, one of the global solar leaders, receives a lot less sunlight annually than any state in the United States besides Alaska, indicating that the price of the electricity and the policies implemented by the government play a huge role for successful solar investments. Additionally, the support of local science projects and a change in people's mentality are also urgently needed.

A 2016 World Bank Report describes how Kazakhstan emerged from the Soviet Union with a well-educated and scientifically literate, but dramatically smaller, labor force that had to fight its research battles with outdated equipment in a bureaucratic scene that was not organized to link knowledge and markets.

Almagul Mentbayeva, a senior researcher at Nazarbayev University, in Astana, who also works for the Institute of Batteries LLC, specializes in advanced materials synthesis and characterization for energy storage systems. Her team, under the lead of Zhumabay Bakenov, has been working to prototype a lithium-sulfur battery electrode and a lithium-ion water battery.

Lithium-sulfur batteries have been thrown into the spotlight because of their potential to achieve higher energy density than lithium-ion battery technology. Sulfur as a cathode has an excellent theoretical gravimetric discharge capacity of 1672 mA h/g, while lithium-cobalt ($LiCoO_2$), the current popular choice for cathode material in mobile phones, laptops, and digital cameras, has 275 mA h/g.

But sulfur as an insulator also has low mass-loading, which leads to low capacity. Furthermore, undesired dissolution of lithium polysulfide ($(Li_2S)_n$, $3 \leq n \leq 8$) species into the electrolyte results in capacity fading. As a result, Li-S batteries suffer from low electronic conductivity and low cycle life.

Mentbayeva and her team have been trying different approaches to solve the issue, mainly by developing new composites and trying encapsulation of the cathode

Luis R. Rojas-Solórzano and Aiymgul Kerimray, School of Engineering, Nazarbayev University, Republic of Kazakhstan
Eva Karatairi, eva.karatairi@gmail.com

https://doi.org/10.1557/mrs.2018.215 Published online by Cambridge University Press

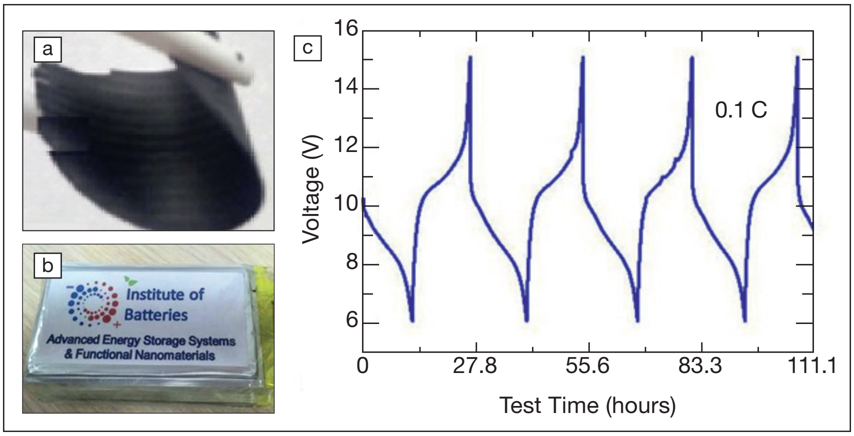
as well as heat and chemical–mechanical treatment. At the same time, they developed several sizes of the prototype and have tried to find markets for it.

"We partly solved the technical problems, and there is definitely interest from the domestic market, as well as the military," she said, "because batteries created for European countries, for example, are not working in the extreme weather conditions of Kazakhstan." But two issues remain difficult to overcome: "First, all of the materials we used had to be imported, something that significantly raises the costs," said Mentbayeva. In addition, although the team is able to construct the electrode, there is no facility that can assemble a real battery prototype, which is a request of potential customers.

Yelena Kalyuzhnova, director at the Centre for Euro-Asian Studies and professor at the University of Reading, discussed the hurdles of commercialization for projects that involve renewable technologies. "Although the crème de la crème of society supports these new ideas, you actually need [the] understanding and support of every family and person in the country. People do not like change, and a change in mentality can be really slow, which can create many excuses as to why we should not put a new technology at the commercial level."

According to Kalyuzhnova, people in key positions in the industry find it hard to connect scientific results with real life problems. "There is lack of information about renewables, and as long as the market fails to appreciate and understand the public benefit of it, it will take a long time before we see wind turbines and solar panels replacing coal plants," she said.

Damir Aidarkhanov is a research assistant and one of the first who helped to establish the Laboratory of Solar Energetics at the Center for Energy and Advanced Materials Science at Nazarbayev University. He has firsthand experience in the Kazakhstan Sustainable Energy Financing Facility of the European Bank for Reconstruction and Development. The project's goal was to transfer knowledge and build expertise, among both banks and companies, showing the energy efficiency and benefits of renewable energy measures.



Examples of the materials produced at the Institute of Batteries, in Astana. (a) A freestanding composite cathode for lithium-sulfur batteries, composed of sulfur, dehydrogenated polyacrylonitrile, and multiwalled carbon nanotubes. (b) A battery stack assembled with cells that contain a sulfur/polyacrylonitrile/ketjenblack (a mixture of carbon black with plastic, rubber, or other materials) composite cathode. (c) A graph that exhibits stable cycling performance of this battery. Credit: Almagul Mentbayeva.

Since 2011, Aidarkhanov has worked to develop third-generation organic photovoltaic solar cells. This year, his team has started research on perovskite solar cells, drawn by the potential to develop a low-cost, industry-scalable technology for devices with high efficiency.

In 2012, the Astana solar manufacturing plant was launched as part of the State Program for Accelerated Industrial-Innovative Development of Kazakhstan. The purpose was to create a fully vertically integrated production cycle of photovoltaic modules to extract and process Kazakhstani silicon for the assembly of solar panels. Around the same time, Solar Silicon was also founded, a startup company engaged in the production of silicon photovoltaic cells.

Both are subsidiaries of KazAtomProm, a company responsible for the import and export of uranium, rare metals, and nuclear fuel in Kazakhstan. They were expected to be a driver of Kazakhstan's planned industrial diversification that would help develop the country's renewable energy technologies sector. However, their performance has been lackluster, and KazAtomProm has been seeking investors to take over the companies. Production at Solar Silicon was suspended in May 2018.

Efforts in establishing themselves in international renewables science has been intense for the Kazakhs. Kalyuzhnova believes that Kazakhstan, at the moment, cannot afford renewables. "The country has a budget, but it is clearly not enough, and investors are needed. This is a financially risky area for traditional funding institutions, and Kazakhstan is looking now at Islamic finance for its green projects," she said.

This year, Kazakhstan established a renewable energy auction policy and intends to tender 1 GW of power capacity. Successful companies will sell electricity to the settlements and tariffs department under a 15-year contract. In the first round of auctions in May, the government awarded just under 100 MW for wind projects. Nineteen contracts were signed for solar, wind, water and bio-gas energy, and more participants are expected for the second round that will be held later this year. According to Saltanat Rakhimbekova, chairwoman at the Coalition for a Green Economy, "As a result of the renewable energy auction held in our country, the price for solar energy made 4.8 cents per kW, which is a more competitive price."

In this ambitious country, which depicts a golden sun and an eagle carried by the wind in its flag, Kazakh scientists have great hope. "We are ready for the hard and creative work," said Aidarkhanov, "and with enough funding, we can make the next big steps." □

2019 MRS® SPRING MEETING & EXHIBIT

April 22–26, 2019 | Phoenix, Arizona

CALL FOR PAPERS

Abstract Submission Opens
September 28, 2018

Abstract Submission Closes
October 31, 2018

Spring Meeting registrations include MRS Membership July 1, 2019 – June 30, 2020

BROADER IMPACT

BI01 High Impact Practice—Increasing Ethnic and Gender Diversification in Engineering Education

CHARACTERIZATION, PROCESSING AND THEORY

CP01 Advances in *In Situ* Experimentation Techniques Enabling Novel and Extreme Materials/Nanocomposite Design
CP02 Design and *In Situ* TEM Characterization of Self-Assembling Colloidal Nanosystems
CP03 Advances in *In Situ* Techniques for Diagnostics and Synthetic Design of Energy Materials
CP04 Interfacial Science and Engineering—Mechanics, Thermodynamics, Kinetics and Chemistry
CP05 Materials Evolution in Dry Friction—Microstructural, Chemical and Environmental Effects
CP06 Smart Materials for Multifunctional Devices and Interfaces
CP07 From Mechanical Metamaterials to Programmable Materials
CP08 Additive Manufacturing of Metals
CP09 Mathematical Aspects of Materials Science—Modeling, Analysis and Computations

ELECTRONICS AND PHOTONICS

Soft Organic and Biomolecular Electronics

EP01 Liquid Crystalline Properties, Self-Assembly and Molecular Order in Organic Semiconductors
EP02 Photonic Materials and Devices for Biointerfaces
EP03 Materials Strategies and Device Fabrication for Biofriendly Electronics
EP04 Soft and Stretchable Electronics—From Fundamentals to Applications
EP05 Engineered Functional Multicellular Circuits, Devices and Systems
EP06 Organic Electronics—Materials and Devices

Semiconductor Devices, Interconnects, Plasmonic and Thermoelectric Materials

EP07 Next-Generation Interconnects—Materials, Processes and Integration
EP08 Phase-Change Materials for Memories, Photonics, Neuromorphic and Emerging Application
EP09 Devices and Materials to Extend the CMOS Roadmap for Logic and Memory Applications
EP10 Heterovalent Integration of Semiconductors and Applications to Optical Devices
EP11 Hybrid Materials and Devices for Enhanced Light-Matter Interactions
EP12 Emerging Materials for Plasmonics, Metamaterials and Metasurfaces
EP13 Thermoelectrics—Materials, Methods and Devices

ENERGY AND SUSTAINABILITY

Energy Storage

ES01 Organic Materials in Electrochemical Energy Storage
ES02 Next-Generation Intercalation Batteries
ES03 Electrochemical Energy Materials Under Extreme Conditions
ES04 Solid-State Electrochemical Energy Storage

Catalysis, Alternative Energy and Fuels

ES05 Cooperative Catalysis for Energy and Environmental Applications
ES06 Atomic-Level Understanding of Materials in Fuel Cells and Electrolyzers
ES07 New Carbon for Energy—Materials, Chemistry and Applications
ES08 Materials Challenges in Surfaces and Coatings for Solar Thermal Technologies
ES10 Rational Designed Hierarchical Nanostructures for Photocatalytic System
ES11 Advanced Low Temperature Water-Splitting for Renewable Hydrogen Production via Electrochemical and Photoelectrochemical Processes
ES12 Redox-Active Oxides for Creating Renewable and Sustainable Energy Carriers

Water-Energy Materials and Sustainability

ES09 Advanced Materials for the Water-Energy Nexus
ES13 Materials Selection and Design—A Tool to Enable Sustainable Materials Development and a Reduced Materials Footprint
ES14 Materials Circular Economy for Urban Sustainability

Photovoltaics and Energy Harvesting

ES15 Fundamental Understanding of the Multifaceted Optoelectronic Properties of Halide Perovskites
ES16 Perovskite Photovoltaics and Optoelectronics
ES17 Perovskite-Based Light-Emission and Frontier Phenomena—Single Crystals, Thin Films and Nanocrystals
ES18 Frontiers in Organic Photovoltaics
ES19 Excitonic Materials and Quantum Dots for Energy Conversion
ES20 Thin-Film Chalcogenide Semiconductor Photovoltaics
ES21 Nanogenerators and Piezotronics

QUANTUM AND NANOMATERIALS

QN01 2D Layered Materials Beyond Graphene—Theory, Discovery and Design
QN02 Defects, Electronic and Magnetic Properties in Advanced 2D Materials Beyond Graphene
QN03 2D Materials—Tunable Physical Properties, Heterostructures and Device Applications
QN04 Nanoscale Heat Transport—Fundamentals
QN05 Emerging Thermal Materials—From Nanoscale to Multiscale Thermal Transport, Energy Conversion, Storage and Thermal Management
QN06 Emerging Materials for Quantum Information
QN07 Emergent Phenomena in Oxide Quantum Materials
QN08 Colloidal Nanoparticles—From Synthesis to Applications

SOFT MATERIALS AND BIOMATERIALS

SM01 Materials for Biological and Medical Applications
SM02 Progress in Supramolecular Nanotheranostics
SM03 Growing Next-Generation Materials with Synthetic Biology
SM04 Translational Materials in Medicine—Prosthetics, Sensors and Smart Scaffolds
SM05 Supramolecular Biomaterials for Regenerative Medicine and Drug Delivery
SM06 Nano- and Microgels
SM07 Bioinspired Materials—From Basic Discovery to Biomimicry

www.mrs.org/spring2019

Meeting Chairs

Yuping Bao The University of Alabama
Bruce Dunn University of California, Los Angeles
Subodh Mhaisalkar Nanyang Technological University
Ruth Schwaiger Karlsruhe Institute of Technology–Institute for Applied Materials
Subhash L. Shinde University of Notre Dame

Don't Miss These Future MRS Meetings!

2019 MRS Fall Meeting & Exhibit
December 1–6, 2019, Boston, Massachusetts

2020 MRS Spring Meeting & Exhibit
April 13–17, 2020, Phoenix, Arizona

FOLLOW THE MEETING!

#S19MRS

MRS MATERIALS RESEARCH SOCIETY®
Advancing materials. Improving the quality of life.

https://doi.org/10.1557/mrs.2018.215 Published online by Cambridge University Press