Increasing environmentally friendly energy production as a priority task of Mongolia's energy industry

Sereeter Batmunkh*

Mongolian university of science and technology, 14191 8th khoroo, Baga toiruu 34, Sukhbaatar district, Ulaanbaatar, Mongolia

Abstract. The article briefly justifies the urgent need to introduce new generating capacity into the country's power system to meet demand for energy and discusses individual issues related to new energy sources. The geographical, climatic, and economic features of the country are compared to those in other countries in the region, and external and internal factors influencing the energy sector are identified. Information is provided on the release of greenhouse gases, their main sources and the measures taken to further reduce them. The article also highlights the main strands of environmentally friendly solutions for the development of energy sources and presents ideas on scientific research in this direction and some of their results. The final part of the article presents an opinion regarding promising intercountry projects and emphasizes the need for Mongolia's energy diplomacy to pay attention to them. **Keywords:** energy source, generating capacity, electrical load density, greenhouse gas, renewable energy source, energy technology.

1 The state of the economy and energy in Mongolia

Now, to a certain extent, the time of instability in the country's economy has passed and power consumption in all social and economic spheres is increasing. Over the past 15-20 years, the annual growth of electricity consumption has been growing steadily and its growth rate remains at the level of 6-7% per year, which indicates the stability of the main economic sectors, including energy. As a result, in 2022, the annual electricity production reached 8.2 billion kWh [1], which increased more than 4 times compared to 2000. Thus, the actual annual electricity production per capita is 2,405.3 kWh/person.

Currently, the electricity supply to the country's consumers is provided mainly from thermal power plants operating as combined heat and power plants. This is due to the fact that the development of the country's energy sector was associated with the industrialization of the country and the simultaneous emergence of industrial cities, where it was necessary to simultaneously cover thermal loads. However, an analysis of the state and development of the country's energy sector as a whole shows that since 2017 the sector has encountered a critical situation due to the insufficient electricity and heat generating capacity. For the first time, it manifested itself in December 2017 when the peak power exceeded the available power of all existing electrical sources. The maximum peak power of the electrical load in the winter of 2022-2023 reached 1,476.0 MW. The installed capacity of all power plants in the country is 1,474.5 MW and the available electrical power does not exceed 1,135.0 MW.

*Corresponding author: batmunkh_acad@yahoo.com

Thus, the domestic electricity generation can cover no more than 80% of the electrical load of consumers. Therefore, the country is forced to import electricity from neighboring countries, mainly from the Russian Federation. Another qualitative indicator characterizing the technical condition of electric power system (EPS) is the auxiliary consumption of electricity by power plants and its losses in networks, which in total amount to ¼ of all distributed electricity. Thus, we import electricity in order to compensate for this expenditure. This is confirmed by the ratios of electricity consumption to its production in recent years, which fluctuate at values close to unity (from 0.96 to 0.99).

To cover the power consumption of the large copper-molbidene enterprise Oyu-Tolgoi, which belongs to the foreign company Reo-Tinto, a special power line was built from China.

2 Features of Mongolia compared to other NEA countries

Mongolia is one of the NEA countries and is located in the very heart of the Asian continent and has a number of specific features that distinguish it from the other countries in the region. The main one is the geographical location, which is shown in Fig. 1.

Fig.1. Geographical location of Mongolia.

To further elaborate, Mongolia has the following distinctive features:

- A vast territory combined with a small population leads to very low territorial densities of energy consumers and also electricity consumption, i.e. power (0.7 kW/km ^{2}) and electrical load (6,112.3 kWh/km ^{2}/year);
- This, in turn, causes difficulties in creating centralized power supply systems and a unified electric power system in the country;
- Climatic features caused by distance from the seas and oceans lead to large fluctuations in average temperature throughout the year and significant differences both between the summer maximum (+40 ^{0}C) and winter minimum (-40 ^{0}C) temperatures, and on a daily scale between daytime and night temperatures during the heating season and make the heating season longer (up to 240 days in the north of the country) ;
- In addition, the absence of access to the world's oceans and the location between two major powers are to a certain extent an obstacle to international communication;
- Finally, the historically prevailing insufficient development and even the absence of many sectors of the economy, including heavy industry. Industrialization started in the middle of the last century and focused mainly on the creation of coal-mining, mining, processing of agricultural products, local production, and **energy industry**.

Mongolia's economy and energy sector are uniquely impacted by both internal and external factors (Fig. 2), setting it apart from other nations.

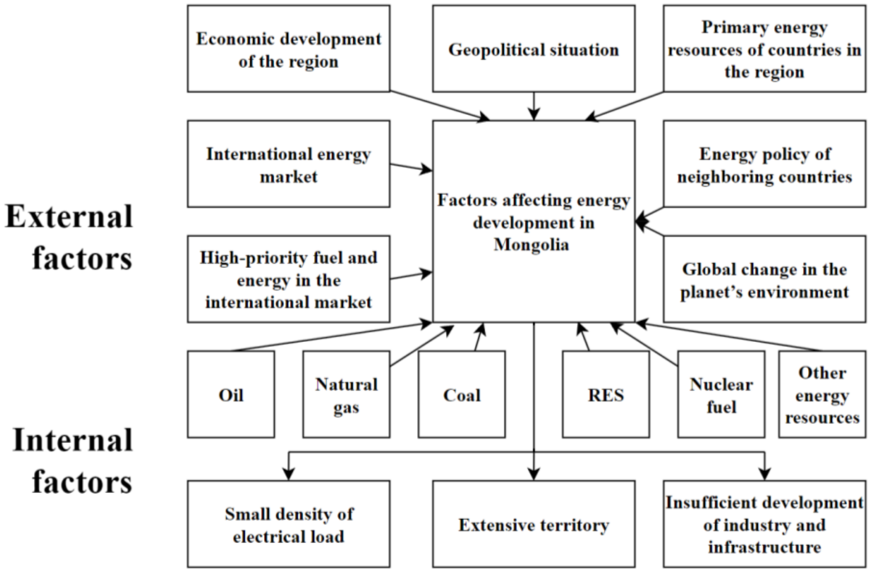

Fig.2. Factors influencing the development of energy industry of Mongolia.

3 The need for new energy sources

In 2022, the available electric power resource, given electricity imports, was 10.3 billion kWh and the winter peak power of the electrical load of the integrated EPS reached 1.47 GW. The annual production of thermal energy was 11.9 billion Gcal. The installed capacity of all electricity sources in the country is 1.5 GW and 81.1% comes from thermal power plants. RES is 18.3%. The average value of the installed capacity utilization factor (ICUF) is 64% and an ICUF of thermal power plants during the winter maximum load ranges from 82 to 92%. The auxiliaries of reserve sources are between 13 and 16%. The transmission and distribution losses amount to 12-13%, for remote EPS this value is slightly higher [1]. Thus, the electricity imports, mainly from the Russian Federation, play a crucial role in meeting demand for electricity and regulating the IEPS, as they provide power reserves.

Therefore, the country requires new, first of all, electricity sources based on local energy resources.

It is important to note that there are sufficient quantities of coal, renewable energies, and nuclear fuel. However, currently mainly coal and a small amount of solar and wind energy are used. The energy resources of the river flow are used in extremely small quantities. The total installed capacity of RES is 278 MW, which is equal to 18% of the total installed capacity in the country. Hydroelectric power stations on the Egiin Gol and Selenga rivers could play a big role both in covering electricity consumption and in regulating peak loads in the Central region of the country, where the largest consumers are concentrated [2],[3]. Now, the construction of the Erdene-Burenskaya hydroelectric power station is (almost) starting in the western part of the country with technical assistance from the PRC.

4 The basis for the creation of environmentally friendly energy sources in Mongolia

In light of the ongoing new trends in climate change and the challenges of our time, which require environmentally friendly energy development, there is a need to review the energy economy as a whole. The main thing here is to reduce the greenhouse gases emitted by coal-fired sources.

In order to show the trend of changes in the overall emission of greenhouse gases, the following data obtained from various sources can be cited: in Mongolia, greenhouse gas emissions amounted to 15.6 million t of CO_2 e in 2006, - 18.57 million t in 2016, and, according to estimates, more than 50.0 million t in 2020. These figures are insignificant (0.05%) compared to global values.

On a global scale, in 2006, 2016, and 2022, the global gross emissions of greenhouse gases (CO_2) were 30,590, 35,520 and 37,490 million t, respectively. In Mongolia, energy and agriculture play a significant role as major contributors to the emission of greenhouse gases. Figure 3 shows the composition of greenhouse gases for 2020 with a focus on the predominant shares of CO_2 and methane (CH_4).

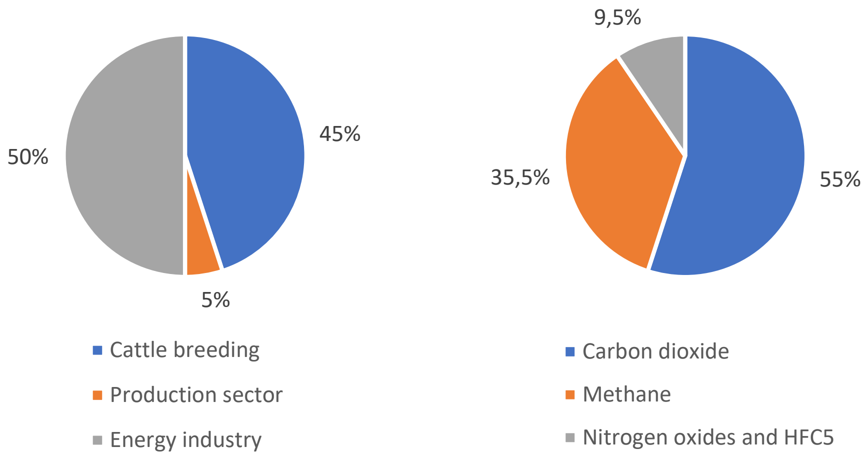

Fig.3. Composition of greenhouse gases emitted in Mongolia for 2020

For a general assessment of the participation of Mongolia's energy industry in the gross output of triatomic gases, data on the net emissions (excluding absorption) of these gases are provided (Table 1).

Table 1. Gross output volumes of triatomic gases, million tons of CO_2e.

Source	2010	2015	2020
Electrical energy generation	6.6	7.6	12.1
Thermal energy production	1.1	2.1	1.8
Coking coal mining	0.4	0.7	1.2
Mining of other types of coal	0.2	0.4	0.6
Total for energy sector	8.3	10.8	15.7

The world average greenhouse gas output per person was 4.63 tons in 2006, 4.76 tons in 2016, and 4.67 tons in 2022. In Mongolia, this indicator was 6.13 tons in 2016, and 27.0 tons (!)in 2020. Thus, the country was significantly ahead of the two large producers of greenhouse gases, China and the USA in terms of this specific indicator. The recent increase in greenhouse gas emissions in Mongolia is primarily linked with mining (44%) and deforestation. There is evidence that about 65% of greenhouse gases are absorbed back. Before drawing a conclusion, it is crucial to pay attention to some of the above-mentioned features of Mongolia, namely: the scale of the country and the structure of economic activity, which are very different from many other countries. However, when compared to Mongolia's population and economic size, greenhouse gas emissions in the country are high and close attention must be paid to this important environmental issue in light of the Paris Agreement.

The greenhouse gases can be cut down in two ways: by reducing their emissions and by intensifying the reduction process.

Therefore, the Vision 2050 program [4] set the goal of reducing greenhouse gas emissions by 22.7% by 2030 through the introduction of **"green technologies"** in all sectors of the economy, primarily in **the energy** and agriculture sectors of Mongolia. On the other hand, on the initiative of President U. Khurelsukh, a national movement called "The Billion Trees" was launched in the country to plant trees and strengthen the soil cover of the territory. Currently, the area of forest ecosystems in Mongolia is 16.7 million hectares, which is equal to 10.4% of the total area of the country. Mongolia also aims to increase the use of renewable energy, support the Asian Super Grid initiative, and cooperate with countries in the region to share its rich solar and wind resources. The Government of Mongolia is taking various temporary measures to mitigate the effects of gas emissions into the atmosphere of cities and allocates considerable funds for this annually. Various regulations on emissions from industry and energy sources are being reviewed in the light of the energy Conservation Law, and lower standards for heat losses of buildings and heating networks have been adopted.

5 Scientific and technological directions for advancement of power generation and the energy sector

The electricity sector in Mongolia requires the introduction of "green energy sources" and "green technologies" for using coal at generating sources. Therefore, it is crucial to conduct research on the selection of feasible ways to ensure environmentally friendly solutions, which is the main challenge facing scientists and energy experts from all scientific, industrial, and administrative entities dealing with energy issues in the country. Mongolian specialists together with scientists from the Institute of Thermophysics of SB RAS have developed a technological framework for a steam generator with a swirl coal combustion technology for a sustainable thermal power plant to make the use of coal from the Shivee-Ovoo deposit environmentally friendly. This solution could not only assist in addressing environmental problems of the energy sector, but also, significantly reduce the metal intensity of the main equipment and the construction volume of the boiler department of the power unit of the thermal power plant in terms of design and technology [5].

Public and industrial energy, along with the heat supply to dispersed consumers are also key issues of energy supply in the country. The majority of scattered consumers rely on heat provided by small boiler houses and individual sources, such as heating and cooking furnaces. However, the efficiency of these sources is quite low ranging from 70% to 80% of calorific value of the fuel. Therefore, environmentally friendly heat supply to these consumers is also one of the primary objectives to be accomplished. One of the solutions here can be the use of distributed sources based on renewable energy resources and gas.

The environmental requirements of our time dictate the need to search for alternative approaches to heat supply issues, which could become innovations in the development of heat supply in Mongolia. We conducted an experiment involving the use of a heat pump installation in combination with solar collectors to provide heating for a kindergarten building in climate zone II in the outskirts of Ulaanbaatar (in the city of Tsetserleg located 45 km from the capital). The created system for using the geothermal energy of the soil consists of 24 wells 100 m deep, equipped with deep heat exchangers in the form of two parallel U-shaped pipes located in a protective cover, the outputs of which are connected by polyethylene tubes to common collectors for supplying and discharging coolant to the heat pump installation. The area of the thermal energy intake field is 48x24 m. This part forms the first forced circulation loop of the low-potential coolant, which is equipped with an independent circulation pump. The second loop connects the heat pump unit with series-connected water reservoirs and transfers high-potential energy to them. This part of the system works to heat the building. Solar collectors were also installed here to cover the need for hot water. Electric heaters were installed in the tanks as a backup heat source. The experimental operation proved to be successful which is confirmed by the measured data given in Table 2.

Table 2. Winter operating parameters of a heat pump-solar heating system of the kindergarten.

Temperature, °C, of	11.23.2010	02.12.2010	08.12.2010	12/10/2010
- Outside air	-12.8	-10.3	-7.9	-16.1
- Refrigerant from the solar collector	+40	+48.6	+46.7	+42.5
- Refrigerant supplied to the room heating system	+53.6	+58.2	+54.4	+49.2
- Refrigerant supplied from the room heating system	+42.1	+46.6	+42.5	+37.4
- Indoor air	+23°C	+23°C	+23°C	+23°C

Thus, the experiment illustrates the possibility of using low-potential heat from the environment according to this scheme for heating public and household off-grid consumers in winter in Mongolia.

To improve the environmental situation in large cities, small heat sources are converted to natural gas. This could be facilitated by Russian pipeline gas. Regarding the “trans-Mongolian gas pipeline” of the Russian Federation-China, experts have substantiated Mongolia’s future need for natural gas for consumers located in the adjacent territories and considered options for Mongolia’s participation in projects for the construction of gas pipelines passing through its territory. These studies show that large gas consumers along the route (see Fig. 4) are concentrated in the cities of Sukhbaatar, Darkhan, Ulaanbaatar, Choir, and Sainshand. Their total annual demand for natural gas was estimated by the research team of Melentiev Energy Systems Institute of Siberian Branch of the Russian Academy of Sciences (ESI SB RAS) at 0.4 –0.6 billion m^3. Mongolian experts estimate the potential annual demand of Mongolian consumers located along the export gas pipeline route for natural gas at 2.0–2.5 billion m^3. It would also be highly beneficial to collaborate with foreign companies to explore advanced technologies for gasifying Mongolia’s brown coals with rich volatiles.

Therefore, Mongolia is interested in such large, regional-scale, international projects planned within the NEA countries, for example, such as the “Russia-China Gas Pipeline” within the framework of the Russian program “Power of Siberia 2,” passing through Mongolia’s territory, projects for the construction of interstate power pools based on the Asian super grid,” and other similar initiatives of the countries in the region, which in one way or another relate to the fuel and energy policy and energy diplomacy of Mongolia.

Fig. 4. Route of Power of Siberia 2 gas pipeline in Mongolia.

6 Conclusions

1) Mongolia is faced with the need to create and commission new energy sources such as large thermal power plants based on environmentally friendly technologies for the use of coal and distributed electricity and heat generation from local and renewable energy resources.
2) Drawing attention of our foreign colleagues and partners to our above-mentioned energy problems is crucial for successfully resolving them.
3) Although not all issues related to the greening of energy production and consumption are included in this list, it does highlight several aspects that can be seen as significant challenges.
4) The acceleration of the international projects proposed by the Northeast Asian countries, would represent a significant step in addressing energy challenges in the region. Furthermore, it would make a remarkable contribution to the advancement of global energy cooperation.
5) Scientific teams of ESI SB RAS and institutes of Mongolian University of Science and Technology and Mongolian Academy of Sciences are working on the methodological framework for the creation of the Unified Energy System in Mongolia with access to the economic and energy space of Northeast Asia, which is crucial for bolstering energy security and expanding the country’s cooperation in the region.
6) It is also important to emphasize the importance of the further development of Mongolian-Russian energy cooperation in the light of new initiatives of both countries and the challenges of our time. Moreover, it is imperative to promote the fuel and energy partnerships and establish and reinforce electrical connections of the Integrated power system and, in the near future, the newly created UEPS of Mongolia with the EPS of China.

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