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COMPARATIVE STUDY OF SOLAR AND WIND POWER PLANT TARIFF AND INVESTMENT COSTS

Ulam-Orgil Choijiljav[1], Uranchimeg Tudevdagva[2*]

[1]Mongolian University of Science and Technology, Mongolia, ulamorgil@must.edu.mn
[2*]Chemnitz University of Technology, Germany, uranchimeg.tudevdagva@informatik.tu-chemnitz.de
[*]Corresponding author: uranchimeg.tudevdagva@informatik.tu-chemnitz.de

Abstract

One of the main directions of sustainable energy is the development of renewable energy. Mongolia is rich in renewable energy resources and has a very favourable geographical location. Therefore, with the construction of solar and wind power plants, these power plants will be able to supply power to half-day and evening peak loads in any season of the year, and to reduce the amount of imported energy from Russia during peak hours. The Renewable Energy Law was enacted in 2007 and revised in 2015 and 2019, and it has successfully met its goal of developing the sector and attracting foreign investors. The law sets a cap on electricity sales in US dollars, which has had a significant impact on system-wide efficiency. Compared to 2007, the average USD exchange rate increased by 143.41%. The price of 1 kWh of electricity increased from 210.68 MNT to 512.82 MNT for solar power plants; for wind power plants, it increased from 111.19 MNT to 270.66 MNT. In other words, the price of renewable energy in our country fluctuates according to the dollar exchange rate, and the US dollar exchange rate has increased by an average of 7% per year over the past 15 years. Therefore, this paper examines how the US dollar tariff in the Renewable Energy Law affects feed-in tariffs.

Keywords: feed-in tariff, investment cost, solar and wind power plant, renewable energy, electricity market, sustainable energy, energy economics

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СРАВНИТЕЛЬНОЕ ИССЛЕДОВАНИЕ ТАРИФОВ И ИНВЕСТИЦИОННЫХ ЗАТРАТ НА СОЛНЕЧНЫЕ И ВЕТРОВЫЕ ЭЛЕКТРОСТАНЦИИ

Улам-Оргил Чойжилжав[1], Уранчимэг Тудэвдагва[2*]

[1]Монгольский Государственный Университет Науки и Технологий, Монголия, ulamorgil@must.edu.mn
[2*]Технический Университет Кемница, Германия, uranchimeg.tudevdagva@informatik.tu-chemnitz.de
[*]Автор, ответственный за переписку: uranchimeg.tudevdagva@informatik.tu-chemnitz.de

Аннотация

Одним из основных направлений устойчивой энергетики является развитие возобновляемых источников энергии. Монголия богата возобновляемыми источниками энергии и имеет очень выгодное географическое положение. Поэтому благодаря строительству солнечных и ветряных электростанций, дневные и вечерние пиковые нагрузки будут покрыты в любое время года, а также будет сокращено количество импортируемой энергии из России в часы пик. Закон о возобновляемых источниках энергии был принят в 2007 году и пересмотрен в 2015 и 2019 годах, он успешно достиг своей цели по развитию сектора и привлечению иностранных инвесторов. Закон устанавливает ограничение на продажу электроэнергии в долларах США, что оказало значительное влияние на эффективность всей системы. По сравнению с 2007 годом средний обменный курс доллара США вырос на 143.41%. Цена 1 кВт*ч электроэнергии увеличилась с 210.68 тугриков до 512.82 тугриков для солнечных электростанций; для ветряных электростанций она увеличилась с 111.19 тугриков до 270,66 тугриков. Другими словами, цена на возобновляемые источники энергии в нашей стране колеблется в зависимости от курса доллара, а курс доллара США за последние 15 лет рос в среднем на 7% в год. Поэтому в данном исследовании авторами рассматривается, как тариф в долларах США в Законе о возобновляемых источниках энергии влияет на льготные тарифы на энергию, произведенную с помощью возобновляемых источников.

Ключевые слова: зеленый тариф, инвестиционные затраты, солнечные и ветровые электростанции, возобновляемые источники энергии, рынок электроэнергии, устойчивая энергетика, энергетическая экономика

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1. Introduction

With the world pursuing a sustainable energy policy, fossil fuels will not be renewable, and fuel reserves will inevitably be depleted. Because oil and coal are not only fuels but also raw materials for many important products, it is important for humans to use them as sparingly as possible. In addition, the global and Mongolian energy sectors continue to focus on renewable energy development policies, as the use of coal and oil as fuel for energy production has serious negative consequences for the environment (Buyankhishig and Ulam-Orgil, 2018).

"Vision – 2050," approved on May 23, 2020, in the framework of Mongolia's long-term development policy, established the economic priorities for the years 2021 to 2030 to include the following:

- Increase the installed capacity of renewable energy to 30%.
- Use of modern and advanced renewable energy technologies in local heating supply.
- Implement the Asian Integrated Energy Network initiative in cooperation with Northeast Asian countries.
- The use of solar, wind, water, biomass, geothermal, fuel cells, and other new sources in line with resource capacity balances is important for the development of renewable energy (Mongolian Government, 2020).

In 2007, the first Renewable Energy Law was passed in Mongolia. Since then, the law has been revised in 2015 and 2019. The revised law stipulates that the renewable energy producer connected to the transmission network has the right and obligation to connect to the transmission point closest to the generator and supply electricity and comply with the requirements of the network dispatcher. The transmission network, on the other hand, is obliged to purchase and transmit electricity supplied by the producer at the tariffs set by this law (Renewable Energy Law, 2019). One of the special provisions of this law is that the price of electricity generated and supplied from renewable energy sources is higher than the selling price of traditional sources, which is a manifestation of the government's major policy in support of renewable energy. In addition, the Investment Law, the Customs Tariff and Customs Tax Law, and the Value Added Tax Law were amended to exempt renewable energy research and production equipment, accessories, and spare parts from customs and value-added taxes. This favourable policy and legal environment pursued by the government has had a significant impact on the successful implementation of renewable energy projects in Mongolia. The study looked at renewable energy tariffs in other countries and how feed-in tariffs are set in those countries (Javadi et al., 2018; Bakhtyar, 2014; Komiyama, et al., 2014; Guild, 2019; Eberhard and Kaberger, 2016; Goodarzi et al., 2018; Yang and Nie, 2016; Masuta et al., 2015; Nair and Sankar, 2014).

Many government policies and regulations are being implemented to increase the development and use of renewable energy sources around the world. For example, after the Fukushima Daiichi nuclear power plant disaster in Japan on March 11, 2011, the Japanese government began a phased energy policy reform. Therefore, the full retail liberalization of the electricity retail market began in April 2016, and the introduction of a market-dependent feed-in tariff system would be a good option for the development of Japan's renewable energy sources (Fuyi, 2017).

The government of Japan introduced the Renewable Energy Feed in Tariff System on July 1, 2012, which is a widely used incentive system to stimulate the development of energy sources. In 2013, electricity from renewable sources accounted for only 2.2% of total electricity generated in Japan, but after the introduction of the feed-in tariff system, this percentage rose to 4.7% in 2015 and increased 2.1 times in just two years (Fuyi, 2017).

Indonesia is an equatorial country and has sun all year round. From 2016 to 2018, the Indonesian government implemented four regulations to increase the value of investment in energy, especially in the renewable energy sector. Feed-in tariff regulation for solar power plants and local tariff regulation have been developed. However, it has been concluded that these regulations still do not provide good incentives for energy developers (Guild, 2019).

Thus, the new feed-in tariffs for the development of renewable energy sources are working well in some countries, but not in others.

The price of 1 kWh of renewable energy is relatively higher than the price of 1 kWh of electricity produced and imported by thermal power plants, and it depends on the exchange rate, so there is a certain price difference (Batzaya et al., 2021; Bani Adam and Miyauchi, 2019; Zhou et al., 2020).

Many countries around the world have introduced a ***feed-in tariff*** (green tariff) system as part of their policy to reduce traditional energy production, which depends on natural resources, and to develop renewable energy (Goodarzi et al., 2018; Von der Fehr et al., 2016; Chawla et al., 2020; Steffen, 2020).

In Mongolia, the feed-in tariff system was introduced in 2015. In addition, the purchase of electricity generated by solar and wind power plants in a single customer model at a fixed price in US dollars negatively affects the efficiency of a single buyer's system in times of large exchange rate fluctuations. This report examines the impact of changes in the US dollar on the selling price and feed-in tariffs for electricity generated by solar and wind power plants, and calculates the feed-in tariffs for new power plants when they are commissioned (OECD, 2019; Frankfurt School of Finance & Management, 2020; Altantsetseg and Ulam-Orgil, 2021; Orolzodmaa, 2021).

2. Methodology of Feed-in Tariff

Many countries around the world have introduced a *feed-in tariff* system as part of a policy to develop renewable energy and to reduce traditional energy production dependent on natural resources . The feed-in tariff system is one of the most widely used incentive policies for the introduction of renewable energy. In 1987, the US Public Utilities Policy Act was considered the world's first feed-in tariff system (Batzaya et al., 2021; Bani Adam and Miyauchi, 2019; Zhou et al., 2020). In Germany, the share of renewable energy production has increased from 3.6% in 1990 to 30% in 2015 as a result of the feed-in tariff system (Erneuerbare Energien Gesetz-EEG) under the Renewable Energy Sources Act (IRENA, 2020).

Although the design and calculation methodology of the feed-in tariff system varies from country to country, the key point of the system is to determine the tariff level.

Determining tariff levels is the most important part of the policy. Tariff rates are usually based on the cost of generating electricity from renewable energy sources. Some studies classify the feed-in tariff system into two main groups. One is a market-independent system, and the other is a market-dependent system. In a market-dependent system, payment depends on the price of electricity, while in a stand-alone market system, payment does not depend on the price of electricity (Fuyi, 2017).

The feed-in tariff policy of the Indonesian Ministry of Energy and Mineral Resources was established to allow users to install solar panels in their systems. This regulation is aimed not only at the use of electricity but also at the supply of electricity using solar panels. There are a number of limitations to the feed-in tariff regulation. The first restriction provides compensation for 65% of the price of energy supplied to the grid (Guild, 2019).

Our country uses a feed-in tariff of a market-dependent system. In doing so, the 2015 reform of the Law on Renewable Energy introduced a special tariff category called "Renewable Energy Feed-in Tariff" instead of incorporating tariffs to support renewable energy production into any type of energy tariff. The law states that feed-in tariffs are tariffs included in energy prices to support renewable energy (Renewable Energy Law, 2019). It also stipulates that the Energy Regulatory Commission will review and approve the price of electricity to be supplied to the system from renewable energy sources and consumer purchase feed-in tariffs.

Feed-in tariffs are defined by the following formula.

$$FiT = \frac{E_{RE}^{\sup}(P_{RE} - P_{SYS}^{avg})}{E_{SYS}^{dis}} \quad (1)$$

where:

E_{SYS}^{dis} – The amount of energy distributed by the system (kWh)

E_{RE}^{sup} – The amount of energy supplied to the system from a renewable energy source (kWh)

P_{RE} – Renewable power plant electricity prices (MNT/kWh)

P_{SYS}^{avg} – The average selling price of the system electricity (MNT/kWh)

From the above formula, it can be seen that the feed-in tariff directly depends on the price and energy supply to the system from renewable energy sources. The Renewable Energy Law sets the price of electricity for renewable energy plants in USD/kWh, and the next chapter discusses how the increase in the exchange rate to MNT/kWh affects the selling price of electricity. The increase in the exchange rate will also affect the level of these feed-in tariffs.

3. Results

3.1. Mongolia's renewable energy sector and investment cost

As of 2020, the installed capacity of Mongolia's power system has reached 1500 MW.

Table 1. Source Structure and Capacity

	Station Type	Installed capacity (MW)	Percentage (%)
1	Thermal power plants	1217	81.13
2	Wind power plants	154.6	10.31
3	Solar power plants	90	6
4	Hydro power plants	23	1.53
5	Diesel stations	15.5	1.03
6	TOTAL	1500.1	100

In terms of total installed capacity, 81.13% are thermal power plants, 17.84% are renewable energy plants and 1.03% are diesel power plants. As of today, three 154.6 MW wind farms and six 90 MW solar power plants are successfully connected to the Central Region integrated system in Mongolia.

As of 2019, Mongolia's total electricity consumption was 8719.1 million kWh, of which 7.49%, or 653.7 million kWh, was supplied by solar, wind, and hydropower plants (Statistical Yearbook of the Energy Regulatory Commission, 2019).

A. Solar power plant investment cost study

Since the adoption of the Renewable Energy Law, 39 companies have received licences to build renewable energy sources with an installed capacity of more than 1500 MW. Today, there are six solar power plants with a total capacity of 90 MW and three wind farms with a total capacity of 154.6 MW.

Table 2 compares the investment costs and other indicators of the planned construction of new solar power plants in Mongolia.

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Table 2. Comparison of Investment Costs of Solar Power Plants

	Key indicators of the project	Nalaikh	Airag	Bayandelger	Choir
1	Capacity	10 MW	20 MW	30 MW	50 MW
2	Investment ($)	15 901 054	35 078 008	46 500 000	80 000 000
3	Area	25 hectares	40 hectares	100 hectares	100 hectares
4	Investment per kW ($)	1590.1	1753.9	1550	1600
5	Area per MW	2.5 hectares	2 hectares	3.33 hectares	2.5 hectares

The table shows that the average investment required per kWh of new solar power plants planned to be built in our country is 1623.25 USD, while the average area per MW is 2.58 hectares. Also, in recent years, new solar power plants have been required to have a battery storage capacity of 20% of their capacity, so the investment cost of a solar power plant is expected to increase sharply to about 2500 USD per 1 kW.

The investment required for 1 kW of solar power plants in the world has been steadily declining since 2010, averaging about 1,000 USD, which is about 60% less than in Mongolia.

B. Wind power plant investment cost study

The first 49.6 MW Salkhit wind power plant was commissioned in Mongolia in 2013, followed by the 50 MW Tsetsii wind power plant in 2017 and the 55 MW Sainshand wind power plant in 2018. The total capacity of wind farms is 154.6 MW. Table 3 compares data from Salkhit, Tsetsii, and Sainshand wind power plants.

Table 3. Comparison of Wind Power Plant Investment Costs

	Key indicators of the project	Salkhit	Tsetsii	Sainshand
1	Capacity	49.6 MW	50 MW	55 MW
2	Capacity of one wind turbine	1.6 MW	2 MW	2.2 MW
3	Number of wind turbines	31	25	25
4	Investment ($)	120 000 000	128 000 000	120 000 000
5	Investment per kW ($)	2419.35	2560.00	2181.81

The table shows that the average investment required for 1 kW of wind power plants built in Mongolia is 2387 USD.

Investment in 1 kW of wind farms around the world has been steadily declining since 2006, with an average investment of about 1400 USD per 1 kW, which is about 70% lower than in Mongolia. In our country (Mongolia), investment costs are high due to high construction and installation costs due to poor infrastructure.

3.2. Price of renewable power plants and feed-in tariffs

A. Solar and wind power plant prices

The Law on Renewable Energy stipulates that the price of 1 kWh of electricity will range from 0.15 USD to 0.18 USD for solar power generation and from 0.08 USD to 0.095 USD for wind power generation (Renewable Energy Law, 2019). However, tariffs have negatively affected the overall efficiency of the energy system, and the initial investment costs have been reduced due to the recent decline in the price of solar panels and wind turbines. As a result, the levelized costs of solar and wind power plants are also declining, which creates conditions for lowering the legal minimum tariffs.

Therefore, 13 years after the law was enacted, an amendment to the law in 2019 stipulates that the price of 1 kWh of electricity will be up to 0.12 USD for solar power and up to 0.085 USD for wind power. In the 15 years since the Renewable Energy Law was first enacted, Mongolia's socio-economic

situation, the structure of the energy sector, and the development of renewable energy techniques and technologies have changed, one of which is the appreciation of the US dollar. Table 4 shows the average exchange rate of the US dollar for 2007-2021 and the rate of change and growth rate of 1 kWh of electricity price for solar and wind power plants.

Table 4. Changes in the Dollar Exchange Rate and Renewable Energy Prices

Year	Average annual USD exchange rate (₮)	Price of 1 kWh of electricity from solar power plants (₮)		Price of 1 kWh of electricity from wind power plants (₮)		Growth percentage
		0.15$ per kWh	0.18$ per kWh	0.08$ per kWh	0.095$ per kWh	-
2007	1170.44	175.57	210.68	93.64	111.19	
2008	1166.1	174.92	209.90	93.29	110.78	-0.37%
2009	1437.9	215.69	258.82	115.03	136.6	23.31%
2010	1356.44	203.47	244.16	108.52	128.86	-5.67%
2011	1265.53	189.83	227.80	101.24	120.23	-6.70%
2012	1359.4	203.91	244.69	108.75	129.14	7.42%
2013	1525.72	228.86	274.63	122.06	144.94	12.23%
2014	1818.28	272.74	327.29	145.46	172.74	19.18%
2015	1970.66	295.60	354.72	157.65	187.21	8.38%
2016	2145.53	321.83	386.20	171.64	203.83	8.87%
2017	2440.63	366.09	439.31	195.25	231.86	13.75%
2018	2472.67	370.90	445.08	197.81	234.9	1.31%
2019	2663.94	399.59	479.51	213.12	253.07	7.74%
2020	2744.38	411.66	493.99	219.55	260.72	3.02%
2021	2849	427.35	512.82	227.92	270.66	3.81%

Compared to 2007, the average USD exchange rate increased by 143.41%. The price of 1 kWh of electricity increased from 427.35 MNT to 512.82 MNT for solar power plants; for wind power plants, it increased from 227.92 MNT to 270.66 MNT. In other words, the price of renewable energy in our country fluctuates according to the dollar exchange rate, and the US dollar exchange rate has increased by an average of 6.88% per year over the past 15 years. Renewable energy prices have risen 2.43 times since 2007 due to the appreciation of the exchange rate. As a result of this increase, the price of electricity for solar and wind power plants has risen sharply.

Table 5 compares the cost of 1 kWh of electricity generated by solar and wind power plants in Mongolia and around the world.

Table 5. Comparison of 1 kWh Electricity Prices

Types	Mongolia ($)	World average ($)	Comparison
Solar power plants	0.12	0.08	50%
Wind power plants	0.085	0.06	41.6%

The price of electricity generated by our solar power plant is $0.12, which is 50% higher than the world average, while the price of electricity generated by the wind power plant is $0.085, which is 41.6% higher than the world average.

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B. Renewable energy feed-in tariffs

The price of 1 kWh of renewable energy is relatively higher than the price of 1 kWh of electricity produced and imported by thermal power plants, and it depends on the exchange rate, so there is a certain price difference (Batzaya et al., 2021; Bani Adam and Miyauchi, 2019; Zhou et al., 2020).

Many countries around the world have introduced a ***feed-in tariff*** (green tariff) system as part of their policy to reduce traditional energy production, which depends on natural resources, and to develop renewable energy (IRENA, 2020; Goodarzi et al., 2018; Von der Fehr et al., 2016; Chawla et al., 2020).

Renewable energy production support tariffs are not included in any energy tariffs, but a special tariff category called "Renewable Energy Promotion Tariffs" is included in an amendment of the Renewable Energy Law in 2015. The law states that feed-in tariffs are tariffs that are included in energy prices to support renewable energy (Renewable Energy Law, 2019). In addition, the Energy Regulatory Commission will review and approve the price estimates for electricity supplied to the energy system from renewable energy sources and the feed-in tariffs.

In our country (Mongolia), the feed-in tariff was 4 MNT per 1 kWh of electricity in 2015, but since then, the production of renewable energy has increased. In 2017, the feed-in tariff increased 2.97 times to 11.88 MNT/kWh, and in 2019, the feed-in tariff increased 5.94 times to 23.79 MNT/kWh. Figure 1 shows the growth of Mongolia's renewable energy feed in tariff.

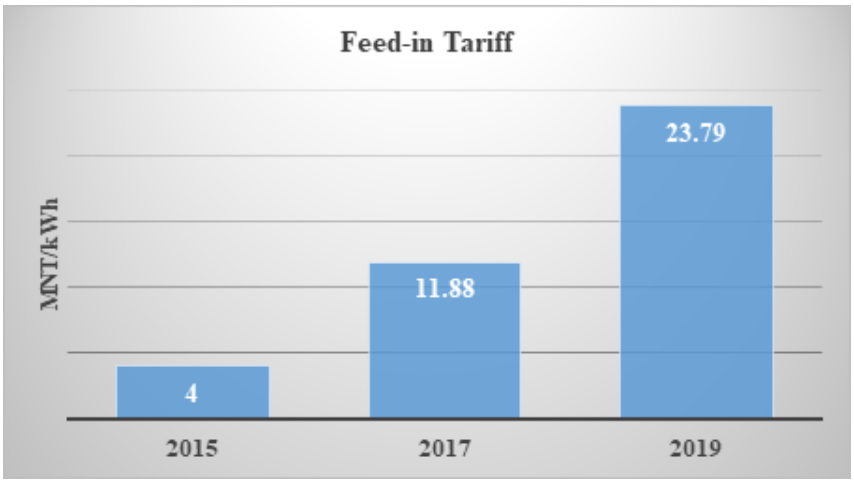

Figure 1. Feed in tariff of renewable energy in Mongolia (MNT/kWh)

In the rest of the world, feed-in tariffs tend to be relatively stable and declining as renewable energy production increases. In the case of Mongolia, the increase in feed in tariffs is very high due to the fact that solar and wind power generation is growing every year, and the exchange rate is rising every year.

This increase in energy feed-in tariffs is the basis for increasing the selling price of electricity throughout the system.

In 2015, electricity from renewable energy sources accounted for only 6.65% of the country's total electricity generation. After the introduction of the feed-in tariff system, this percentage reached 11.54% in 2017 and 16.63% in 2019. Feed-in tariffs allow for a sustainable supply of renewable energy, cover operating costs, and provide a certain level of profitability for investors and producers. Therefore, this article calculates the feed-in tariffs for solar and wind power plants that are planned to be built in recent years when they are connected to the energy system.

Figure 2 shows the rates of renewable energy feed in tariffs in some countries of the world in 2015, 2017 and 2019.

Figure 2. Renewable energy feed in tariffs in some countries of the world (USD/kWh)

Table 6 shows the preliminary feed-in tariff estimates for the 30 MW Gobi Solar Power Plant, which is scheduled to be commissioned in 2020, and the 102 MW Khanbogd Wind Power Plant, which is scheduled to be commissioned in 2023, in the Central Region Integrated System.

Table 6. Calculation of Feed-in Tariff

Specifications	The amount of electricity produced (thousand kWh)	Feed-in tariff (MNT/кWh)
30MW Gobi Solar Power Plant	42048	1.75
102MW Khanbogd Wind Power Plant	330602.4	7.79
Weighted average tariff		7.11

The feed-in tariff for the 30 MW Gobi Solar Power Plant is estimated at 1.75 MNT/kWh, while the feed-in tariff for the Khanbogd Wind Power Plant is estimated at 7.79 MNT/kWh. The weighted average feed-in tariff for these two sources is 7.11 MNT/kWh. In other words, it is estimated that the feed-in tariff for these stations will increase to 30.9 MNT/kWh when they are commissioned.

4. Discussion

The price in US dollars in the Renewable Energy Law has fulfilled its obligation to attract investment. Compared to 2007, when the law was passed, the average exchange rate of the US dollar increased by 143.41%. The price of 1 kWh of electricity for solar power plants increased from 210.68 MNT to 512.82 MNT, and for wind power plants from 111.19 MNT to 270.66 MNT; in both cases, the price increased 2.43 times. In other words, the price of renewable energy in our country fluctuates with the exchange rate of the US dollar, and the exchange rate of the US dollar has increased by an average of 6.88% per year over the past 15 years. Therefore, it is recommended that this proposal be taken into account when amending the Renewable Energy Law, as the sale of electricity in MNT has the positive effect of minimizing the impact of dollar fluctuations on consumer purchase prices.

If a 30 MW solar power plant and a 102 MW wind power plant are added to the system, the feed-in tariff is estimated to increase to approximately 31 MNT/kWh. Although consumer tariffs will increase by this amount, feed-in tariffs will play an important role in supporting and developing renewable energy.

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5. Conclusion

Currently, renewable energy accounts for about 18% of Mongolia's total installed capacity and generates 653.7 million kWh of energy annually from renewable sources. As mentioned above, this indicator is expected to grow rapidly in the future.

Mongolia's investment cost per kWh is about 60% higher than the world average for solar power plants and about 70% higher than the world average for wind power plants. This is because Mongolia is not a technology producer, and the infrastructure is underdeveloped.

In the future, it will be necessary to create competition in the renewable energy sector and focus on reducing investment costs due to lower world prices for equipment and technology, as well as lower energy prices for solar and wind power plants. Therefore, if the company offering the lowest price has the principle of building solar and wind power plants, it will be possible to reduce the price of electricity supplied to the energy system from renewable energy sources.

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About authors:

1. Ulam-Orgil Choijiljav, Ph.D, Associate professor Job position: Associate professor, Power Engineering School, Mongolian University Science and Technology, Ulaanbaatar, Mongolia. ulamorgil@must.edu.mn.

2. Uranchimeg Tudevdagva. Doctor of Science, ScD, Professor, Chemnitz University of Technology, Chemnitz, Germany, https://orcid.org/0000-0001-9239-0760, uranchimeg.tudevdagva@informatik.tu-chemnitz.de.

Информация об авторах:

1. Улам-Оргил Чойжилжав, Кандидат наук, Доцент, Монгольский Государственный Университет Науки и Технологий, Улан-Батор, Монголия. ulamorgil@must.edu.mn.

2. Уранчимэг Түдэвдагва, Доктор наук, Профессор, Технический Университет Кемница, Кемниц, Германия. https://orcid.org/0000-0001-9239-0760, uranchimeg.tudevdagva@informatik.tu-chemnitz.de.