Hydrogen production possibility using Mongolian renewable energy

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A Dorjgotov[1], B Ulziidelger[1], J Yunseong[2], K Oh Chan[2], J Ok Sung[2] and S Yong-Gun[2]

[1]Department of Chemical Engineering, School of Applied Sciences, Mongolian University of Science and Technology, 8th khoroo, Baga toiruu 34, Sukhbaatar district Ulaanbaatar, Mongolia 14191
[2]Inorganic Material Laboratoty, Department of Chemical and Biomolecular Engineering, College of Engineering, Yonsei University, 50 Yonsei-ro, Seodaemun-gu, Seoul, South Korea

Email: gotovmust@yahoo.com

Abstract. There is widespread popular support for using renewable energy, particularly solar and wind energy, which provide electricity without giving rise to any carbon dioxide emissions. Harnessing these for electricity depends on the cost and efficiency of the technology, which is constantly improving, thus reducing costs per peak kilowatt, and per kWh. Utilizing solar and wind-generated electricity in a stand-alone system requires corresponding battery or other storage capacity. The possibility of large-scale use of hydrogen in the future as a transport fuel increases the potential for both renewables and base-load electricity supply.

1. Introduction.

Hydrogen fuel cell vehicles are considered to be an alternative potential replacement of conventional fossil fueled internal combustion engine vehicles. There are several obstacles for the widespread application of hydrogen fuel cell vehicles, for example high capital and operating costs and lack of hydrogen infrastructure. However, several automobile manufacturers have committed to develop vehicles using hydrogen. The attraction of using hydrogen as an energy carrier is that, if hydrogen is prepared without using fossil fuel inputs, vehicle propulsion would not contribute to CO_2 emissions, along with its high energy concentration per unit weight. The drawbacks of hydrogen use are low energy content per unit volume, high tank weights, very high storage vessel pressures, the storage, transportation and filling of gaseous or liquid hydrogen in vehicles, the large investment in infrastructure that would be required to fuel vehicles, and the inefficiency of production processes [1]. Construction of infrastructure for hydrogen fuel is of interest as it can increase economic feasibility of clean energy as well as it contributes to further technical advancements. Production of hydrogen using renewable energy based on wind and solar energy is one of choice of best technologies [2]. Not only does Mongolia have abundant sources of renewable energy, the cost for lowering emissions is extremely low compared to most countries, and the world's most energy hungry market is right next door. On the other hand, the wide regions distribution of renewable energy resources in Mongolia is giving a on-site production possibility of hydrogen [3].

2. Resent application of renewable energy in Mongolia and future

In 2016 Mongolia generated 5.8 billion kWh in total. The power generated by the thermal power plants accounts for 95.8%, power generated by diesel stations is 0.2%, and 4.2% is generated by renewable energy sources. Also 1.9 billion kWh of electricity is imported. The interest of investors in Mongolian energy sector is considerably high which can be clearly seen from the fact that the total sum of capacity of special permission granted to renewable energy projects has reached 879.2 MW by the September of 2017 [4].

At present, close to 90,000 independent solar PV systems are reportedly in use by herders for operating lights, radios, TVs and satellite dishes. Government is also working with JICA /Japan/, GTZ /Germany/ and World Bank in the development of a comprehensive programs for off-grid aimags and soums. Under these programs already replaced diesel set in 198 soum centers, placed diesel + photovoltaic units in 15 soum centers. The capacity of these units vary from 5 kW to 200kW. The first ever large-scale solar power plant with capacity of 10MW has been constructed in Darkhan City in 2017 [5-6].

At present time, over 4000 portable, small wind generators with capacity from 50 W to 150 W are used by herders for operating lights, radios, TVs in rural area. In last years, number of feasibility studies were made for the construction of wind power plants with capacity of 50 MW at ”Salkhit uul”,near capital city Ulaanbaatar and 100 MW in ”Umnigobi” province. Wind power utilization in Mongolia is still negligible [7].

The result of discussions held between Mongolia and Chinese officials on the high political level, the technical and economic assessment has been developed for exporting electricity to the Chinese market in 2011. The initiative to build the Asian Super Grid, in which Mongolians southern Gobi’s solar and wind power resource is to be utilized, and research work on this regard has been carried out with Asian Development Bank’s financing. The idea of the Asian Super Grid, also known as Gobitec is a development vision promoted by Softbank’s Masayoshi Son that envisions the creation and development of a transmission grid infrastructure (High Voltage Direct Current HVDC) connecting Russia, Mongolia, China, Japan and Korea with the intent of providing the connected countries with renewable energy from the Gobi Desert. If this idea comes to fruition, development on a massive scale can be expected to take place in the Gobi Desert (figure 1).

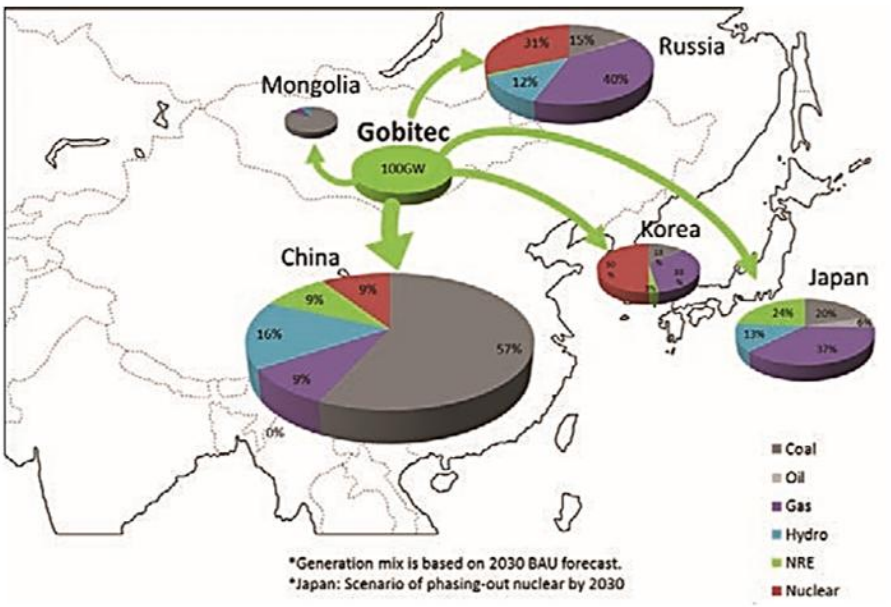

Figure 1. Asian super grid

Based on calculations to build 50 GW solar and 50 GW wind, it is estimated that 900’000 new jobs will be created in Mongolia alone from 2015-2030. Participating countries will reduce 187 Gt CO_2 per

year. A total of 7’530km of transmission line will be needed to be built. The total investment cost is calculated at $293 billion with additional yearly maintenance and service cost of $7.3 billion [8].

3. Capacity of solar energy

Mongolia has substantial solar energy potential. The high intensity of solar radiation, long periods of sunshine, high air transparency, and constant presence of moisture in the air favor the development of solar energy in Mongolia. The annual number of sunshine hours in the same place is within the range of 2450-3300, which is higher than the average duration of sunshine in other countries located along the same latitude (figure 2). Approximately 70% of the total land area receives solar insolation at the rate of 3.4-6.0 kWh/m^2 per day. According to long-term expertise estimates, the solar radiation by square units increased, at the point of direction, from North to South and, at the range, from 2500 kWh/m^2 to 3550 kWh/m^2 per year [9]. The average solar radiation received by Mongolia comes to 3000 kWh/m^2 per year (figure 3).

Southern province Umnugobi aimag have abundant solar energy potential. In the region, solar radiation is 5.4 kWh/m^2 per day and the radiation area is 5542 km^2. If we assume that the area is covered by solar panel, it will generate 1.092.000 GWh electric energy per year, which is equal to 1% of world total energy consumption in 2017. The minimum potential resource of solar energy is 1500 GW, which can be generate 4.774.000GWh electric energy per year by the calculation of DOE (table 1).

Table 1. Solar radiation, potential area and electric energy

Calculated, kWh/m^2 day	Potential area, km^2	Electric energy, GWh/year
3.4	5269.5	654000
3.8	3924.7	544000
4.1	4210.6	630000
4.5	4514.8	742000
5.4	5541.9	1092000
Total	23461.5	4774000

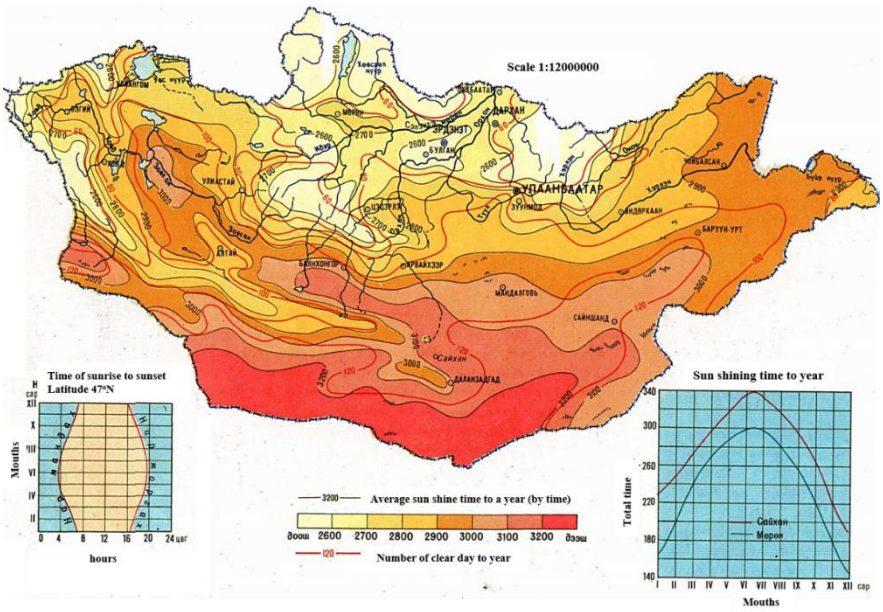

Figure 2. Duration of sunshine in Mongolia

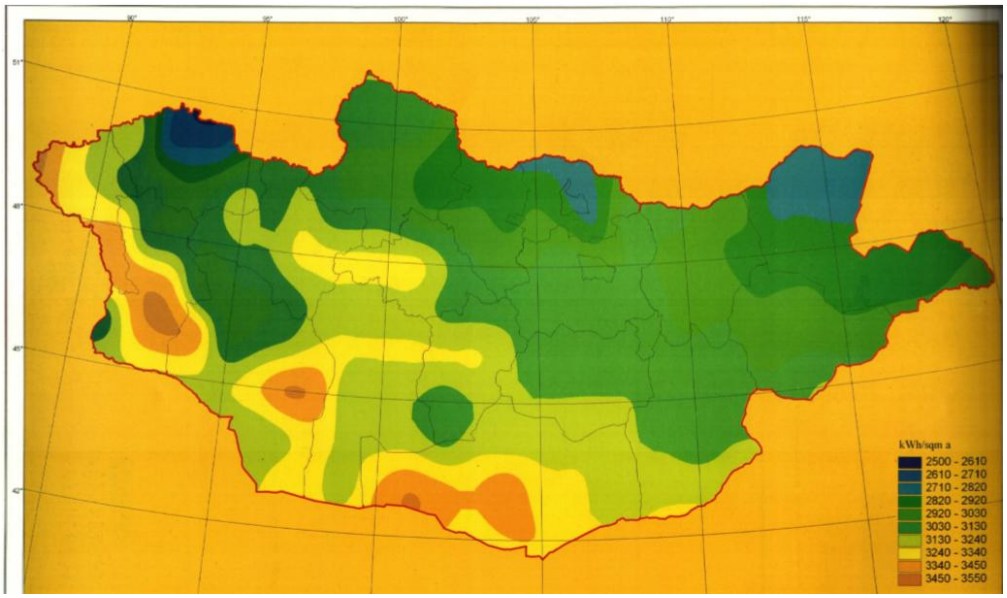

Figure 3. Direct normal solar radiation per year

4. Capacity of wind energy

In year 2000, The National Renewable Energy Laboratory of USA developed a wind energy resource map for Mongolia in cooperation with The Renewable Energy Center of Mongolia and The National Institute of Meteorology of Mongolia (figure 4). The map shown six categories considering wind power density regions.

All territory of the country is under influence of westerly mid-latitude jet stream, a high-speed ribbon of air several kilometers above sea level. The windy land mainly placed in southern and western part of the nation in Gobi and steppe region of the country. More than 10% of the total territory has been estimated to have good-to-excellent wind energy potential for utility scale wind energy applications. Regions in Mongolia with more than 160.000 km^2 area have possibility and are convenient to use high capacity wind power stations [10]. By the assumption, wind power density is about 7 MW/km^2, this amount of windy land could support over 1.100 GW of installed capacity, and deliver over 2.550.100 GWh electric energy per year (table 2). More than 40% of total territory of the country has been estimated to have moderate-to-good wind energy potential, which is suitable for rural power applications. This amount of windy land could support over 4.300 GW of installed capacity, and deliver over 8 trillion kWh per year by conservative estimations. All aimags of Mongolia have at least 6000 MW wind energy resource. Of which, 9 aimags have more than 50000 MW wind energy resource, southern province Umnugobi aimag have 300000 MW wind energy resource.

Table 2. Parameters of good-to-excellent windy lands at 30 m

Categories	At 30m level from land surface		Windy area		Capability, MW	Power per year GWh
	Wind power density, W/m^2	Wind speed, m/s	Area, km^2	%		
1	300-400	6.4-7.1	130.665	81.3	905500	1975500
2	400-600	7.1-8.1	27.165	16.9	188300	511000
3	600-800	8.1-8.9	2.669	1.7	18500	60200
4	800-1000	8.9-9.6	0.142	0.1	1000	3400
	Total		160.641	100	1113300	2550100

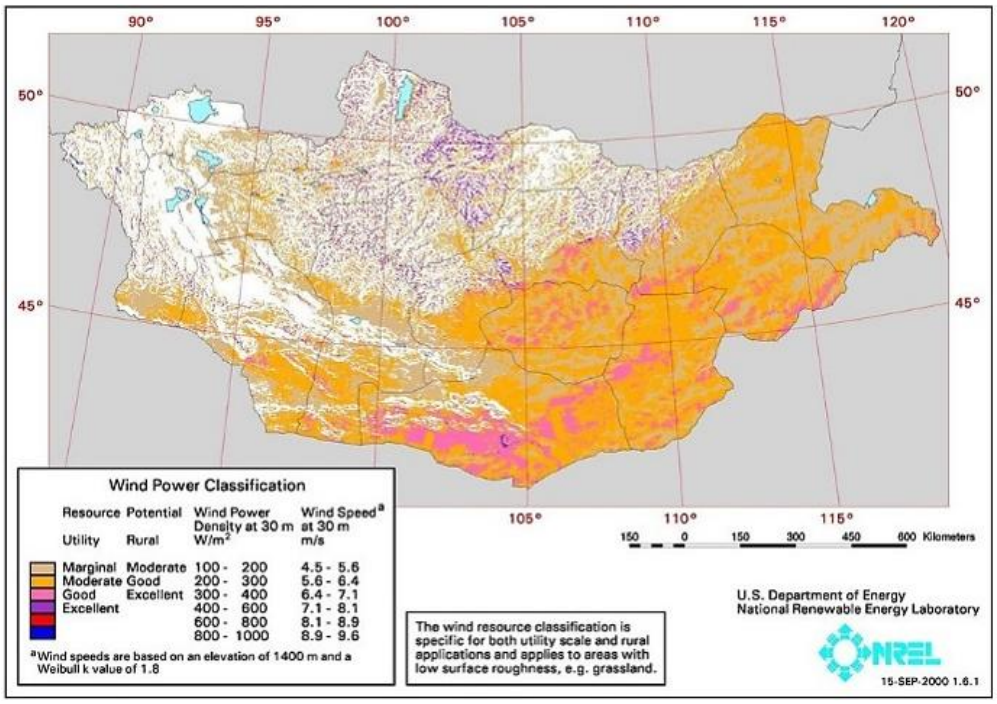

Figure 4. Mongolian wind resource map

5. Hydrogen production possibility

Hydrogen gas production through solar energy which is abundant, clean and renewable is one of the promising hydrogen production approaches.

The average efficiency of photovoltaic cells (PV) is about 20%, the average efficiency of alkaline electrolyser is 80% and the total efficiency of the system will be 16%. PV-electrolyser system with 16% total efficient requires 250 kWh of solar energy to produce 1 kg of hydrogen. Potential solar energy in the Mongolia is estimated to be more than 4.774.000GWh, enough to produce over 19 billion tonn/year of hydrogen. If the PV-electrolyser system set in Southern Umnugobi province, which have more solar energy potential, it will produce 4.35 billion tonn/year of hydrogen from the 5542 km^2 area. It is possible to produce 784 tonn/year hydrogen in 1 km^2 square.

In the case wind energy, efficiency of wind power plants is about 35%, which is higher than PV, the average efficiency of alkaline electrolyser is 80% and the total efficiency of system will be 28%. Potential wind energy in the Mongolia is approximately 2.550.100 GWh from 160641 km^2 good-to-excellent windy lands. It is possible to produce 18 billion tonn/year of hydrogen using total wind energy source because the total efficiency of system is 28%. If the wind power plants-electrolyser system set in excellent windy location with 29834 km^2 area, it can be produce 574600 GWh energy and 4 billion tonn/year of hydrogen. It is possible to produce 136 tonn/year hydrogen in 1 km^2 square of the excellent windy location. There is impossible to produce large amount hydrogen using hydro energy due to low capacity.

In the case power plant electricity is used to hydrogen gas production, electricity cost is approximately 3 $ per 1 kg hydrogen gas because 1kWh electricity price is 0.072 $ in Mongolia. If electricity from renewable resources is used to hydrogen gas production, electricity cost is approximately 1.37 $ per 1 kg hydrogen gas, it is about 2 times cheaper than power plant electricity.

6. Conclusion

5542 km^2 area of Southern Umnugobi province have huge solar energy potential, which is only 3.36% of the province and 0.35% of Mongolian territory. In the region, solar radiation is 5.4 kWh/m^2 per day.

If we assume that the area is covered by PV panel, it will generate 1.092.000 GWh electric energy per year.

Solar radiated hydrogen productivity is 5.76 times higher than wind powered hydrogen in unit area due to dense solar radiation density and long sunshine durability. It is possible to produce large amount of hydrogen in Gobi and steppe region of the country using solar and wind energy. The total calculated hydrogen productivity using sum of solar and wind potential energy is 37 billion tonn/year. The hydrogen productivity in unit area is 920 tonn/year·km^2 by the combine of sum of solar and wind energy. On-site production of hydrogen is also high possibility because 40% of total territory have moderate-to-good wind energy potential and 70% of total territory have 3.4-6.0 kWh/m^2 per day direct solar radiation. North and western regions of the country, which is mountains area, has low solar and wind potential energy. In this regions, on-site production of hydrogen is possibility using solar, wind and/or hydro energies. Possibility to large amount hydrogen production is low in the regions.

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