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Potential Assessment of Wind Solar and Geothermal Resources in Afghanistan for Sustainable Energy Industry

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Abstract

In ongoing of long conflict (almost forty years) and security issues in Afghanistan, there is electricity and environmental shortage issues. The conflict and climate changes to cause drought, air and water pollution, deforestation, soil degradation, overgrazing, desertification, and overpopulation in urban areas, for instance, Kabul city; the pollution always cover the city especially in winter when the wood and coal-fired space heaters provide the houses heating increase the pollution. Afghanistan is not an industrial country, the pollution comes from the transportation system and burning of the biomass and coals for cooking and heating. Before the civil war, there was electricity bus system in the Kabul city. The electricity networks is limited to the cities and province centers. The power demand is increasing year by year and day by day. However, all residents of the cities don't have access to the electricity, and there is load covering issue, especially in Kabul city. The primary source of the electricity supply is the insecure and expensive imported power from the neighboring countries. However, there is the tremendous potential of renewable energies in the country. The existence of domestic clean energy resources, environmental issues, and decrease of renewable technologies cost created demand for power generation form the renewable resources. As the results, the total calculated implementable potential of annual generation would be; 342,521 GWh from wind energy, 140,982 GWh from solar PV, and about 6,000 GWh from CSP (Concentrating Solar Power) technologies those are 160 times of the existing power supply. In addition, the site potential or heat content of geothermal resources are above 5.6x1022Joule (equaling to 15.55x109 GWh). According to the Afghanistan's power sector master plan, that the annual gross electricity demand would be 22,534.3GWh in 2032. This annual demand is equivalent to 8.11x1016 Joule energy. Only, the geothermal resources site potential is almost 0.69 million times of the required one year energy. Of course, the implementable potential of geothermal resources would be much less than the theoretical potential. The exploitable potential of geothermal resources require further analysis considering the environmental, economic, and technical feasibilities.

Keywords: *Renewable energy sources; Solar; wind; geothermal resources analysis*

1. Introduction

Afghanistan is a landlocked mountainous country located in the south Asia, surrounded by Pakistan, China, Iran, Turkmenistan, Uzbekistan, and Tajikistan, one of the low-income country in the global group of incomes. Afghanistan produce the low level of CO2 in the world, the annual spreading of CO2 each person is 3.14% of CO2 spreading each person in Japan. In 2016, the total population was above 34.66 million people, annual GDP (gross domestic product) was 19.47 billion US$, annual GDP per capita was 561.7 US$, and the annual electricity consumption per capita was only 141kWh, one of the low level of

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electricity consumption in the world. For example, the ratio of total GDP and electricity consumption per capita between Afghanistan and Japan were 0.39% and 1.8% respectively in 2016. The economic growth of a nation has a direct relationship with access to the electricity; they are connected 90% to each other. In other words, access to the electricity or its generation from the sustainable domestic resources is one of the important agents in the economic growths and country development.

Fig. 1 shows an annual growth of power plants installed capacity, consumption, generation, and imported electricity of Afghanistan. The increase in electricity during 2005- 2014 were; (1,000 to 4,700) GWh consumption, (934 to 1049) GWh generation, and (105 to 3710) GWh imported power. The installed capacity had been increased only from 524 to 599 MW. The average annual growth of power consumption, generation, and imported electricity in that duration were 18.74%, 2.51%, and 57.05% respectively. The annual electricity demand growth is more than 50%. The domestic power generation is not increased considerably to meet the load requirements. The primary sources of electricity are insecure imported thermal power generation. Except, only 4% of imported amount is hydro power from Tajikistan. The imported power created technical, environmental and economic issues. Technically, they are not operating in a synchronize system. Each power system of the neighbors countries supply the separate region. The domestic electricity generation is from hydro and thermal power plants. The 85% of domestic power generation comes from the hydro power. Till now there is no any grid-connected wind, solar, and geothermal power plant in the country.

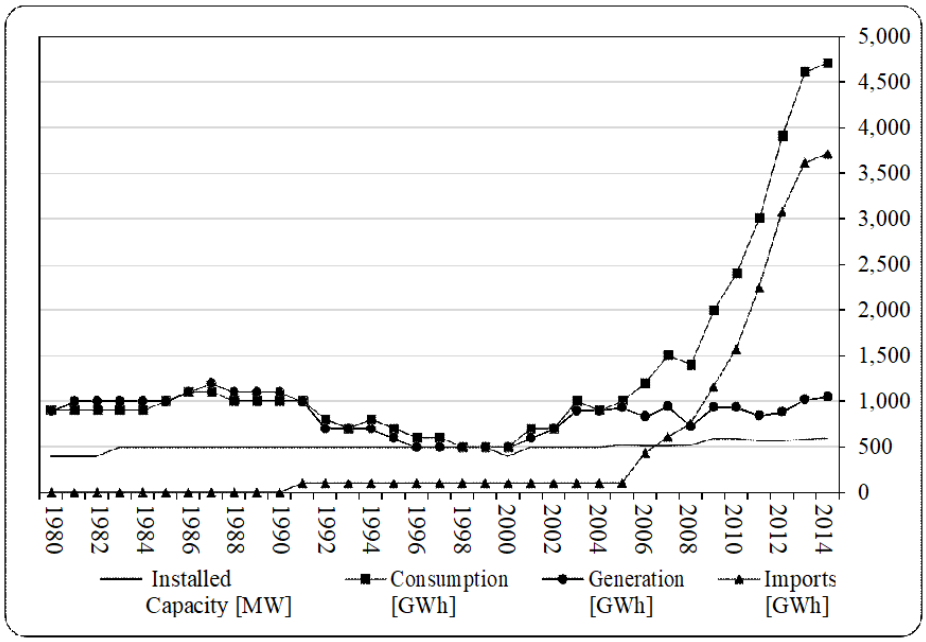

Figure 1: History of Electricity Generation and Consumption in Afghanistan

There are nine geographically distinct power networks in the country. They are divided by four significant grids:

- NEPS: Northeast Power System supplied by four different asynchronous power generations such as domestic, and three imported (from Tajikistan, Uzbekistan, and Turkmenistan).
- SEPS: Southeast Power System is Kandahar and Helmand region power grid which is supplied by domestic power plants.

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- Herat: supplied by three different asynchronous power generations. They are domestic, and two imported from Iran and Turkmenistan.
- Nimroz: supplied by imported power from Iran.

This study could be useful for electrical energy producers, investors, and government planners for electricity generation and power sector development in Afghanistan. Table 1 determines the global view, environmental situation, and economy profile of Afghanistan and its comparison with Japan.

Table 1: Global, environmental, and economic profiles of Afghanistan and Japan.

	Countries	Afghanistan		Japan	
	Indicators and Years	2010	2016	2010	2016
World view	Population, total (millions)	28.8	34.66	128.07	126.99
	Population growth (annual %)	2.8	2.7	0	-0.1
	Surface area (sq. km) (thousands)	652.9	652.9	378	378
	Population density (people per sq. km of land area)	44.1	53.1	351.3	348.4
	Life expectancy at birth, total (years)	61	63	83	84
	Fertility rate, total (births per woman)	5.8	4.8	1.4	1.5
Environment	Forest area (sq. km) (thousands)	13.5	13.5	249.7	249.6
	Protected areas (% of total territorial area)	...	0.5	...	2.1
	Annual freshwater withdrawals (% of internal resources)	...	4	18.9	18.9
	Improved water source (% of population with access)	48	55	100	100
	Improved sanitation facilities (% of accessed population)	29	32	100	100
	Urban population growth (annual %)	4.3	4.3	0.9	0.3
	CO2 emissions (metric tons per capita)	0.29	0.3	9.15	9.54
	Electric power consumption (kWh per capita)	83.33	141	8,595	7,820
Economy	GDP (current US$) (billions)	15.94	19.47	5,700.1	4, 939.38
	GDP growth (annual %)	8.4	2.2	4.2	1
	Inflation, GDP deflator (annual %)	9.4	5.3	-1.9	0.3
	Agriculture, value added (% of GDP)	27	22	1	1
	Industry, value added (% of GDP)	22	23	29	29
	Services, etc., value added (% of GDP)	51	55	70	70
	Exports of goods and services (% of GDP)	10	7	15	18
	Imports of goods and services (% of GDP)	45	49	14	18
	Mobile cellular subscriptions (per 100 people)	36	66	96.8	129.8
	Individuals using the Internet (% of population)	4	10.6	78.2	92
Global links	Merchandise trade (% of GDP)	35	50	26	25
	Personal remittances, received (current US$) (millions)	342	431	1,684	3,819
	Foreign direct investment, (current US$) (millions)	54	99	7,441	34,905
	Official development assistance received (millions US$)	6,471	704, 2	39.2	...

Source: World Development Indicators Database

2. Potential of Renewable Energies

Similar to Afghanistan Renewable Energy Department (ARED) information, they are reported 5149 renewable energies projects as mini and micro grids power supply systems in the whole country. These projects were implemented like micro-hydro power, solar, wind and biomass energies generation. The majority of the projects are under 100kW and below 1MW, except one project is 1MW. Afghanistan is gifted with a vast potential for renewable energy, including hydro, wind, solar, and geothermal energy can also notably provide the sustainable power to the existing grid and future expansion. It has the potential to produce 23,000 MW of

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hydro power, with only 260 MW having been developed so far for large-scale power generation moreover, around 36.6MW as micro-hydro power generation. The hydro power data is not available, therefore, in this study the wind, solar, and geothermal energies are analyzed for further details.

3. Potential of Wind Energy

We have huge wind energy potential in Afghanistan. The Afghanistan west is popular for strong wind nearly 120 days per year. NREL of US published the wind power map for Afghanistan in 2007. The map declare the 31,611km2 area has wind speed above class 4 (wind speed above 6.8m/s, and wind power density above 400W/m2). The assessment calculated that the wind power installation capacity is 158.1GW by assuming 5MW turbines in each km2 area. Fig 2 shows the map of wind power potential and its classification. The wind power potential is classified into seven categories according to the wind power density and speed from the poor to the super (class 6) and outstanding (class 7). The wind energy production is dependent on the wind turbine (wind energy converter) type and available wind speed. The development of wind turbine technology in the future will facilitate the power production in the low wind speed regions as well. Now, it is possible to install the utility-scale wind turbines in class three (wind speed above 6.1m/s) regions. In this case, the total available areas of wind energy above class three is 98,851 km2. If the NREL's calculated wind power density (W/m2) and the total available areas are considered, the total annual wind energy site potential is 0.34x109 GWh (equaling to 1.22x1021 Joule). Of course, not all of this potential is achievable. Determining the implementable potential needs further study and research. Two basic disadvantages of wind power are including primary cost and immaturity of technology offshore wind produces more energetic than onshore wind energy, but is costly much more to establish. The initial costs of wind turbines are being including construction and maintenance.

The merits of wind power are as follow:

- Wind power is costly effective.
- Wind creates jobs opportunity.
- Wind enables industry boost and effectuality.
- It is entirely cleaned fuel source.
- Wind is regarded domestic source of energy.
- It is sustainable, grassroots and permanent.
- Wind turbines can be built on existing farms or ranches.

Wind is a clean part of renewable source of energy that produces no air contamination or water pollution. And since the wind is entirely free, operational costs are most commonly zero once a turbine is erected. Mass production and technology promotion are making turbines cheaper and unexpansive, and many governments offer tax inventiveness to spur wind energy development.

Table 2: Meteorological wind towers data summary.

Site No	Province	Name	Latitude	Longitude	Elevation	Months
Site 1	Parwan	Jabal Saraj	35° 07.53'	69° 14.09'	1,671m	15
Site 2	Balkh	Uljato	36° 43.27'	67° 37.33'	374m	14
Site 3	Balkh	Sari Tangi	36° 37.67'	67° 41.96'	1,009m	11
Site 4	Kabul	Naghlu	34° 37.32'	69° 41.75'	1,198m	11

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Site 5	Herat	Urdu Khan	34° 18.76'	62° 16.06'	958m	12
Site 6	Herat	Hotel Safid	34° 24.32'	61° 49.35'	876m	13

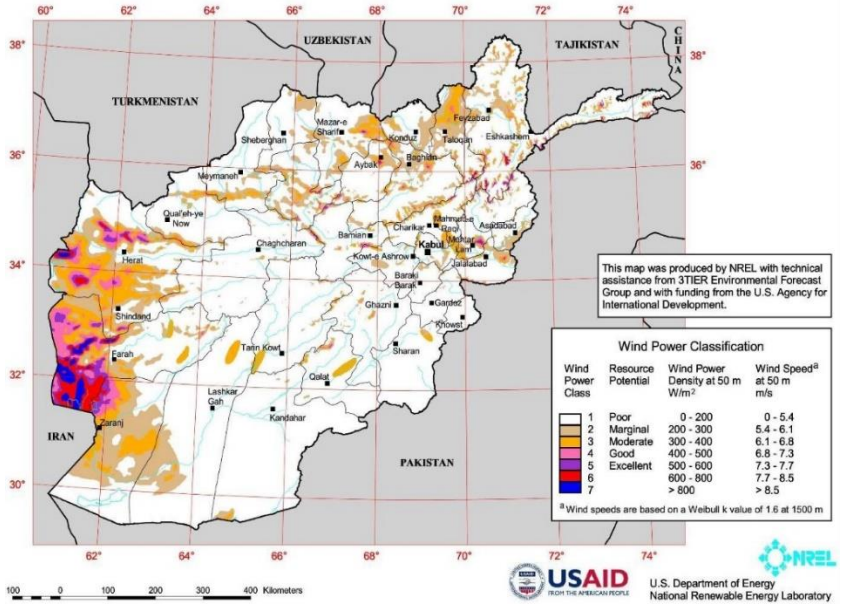

Figure 2: Wind power map of Afghanistan

Table 3: Continued: Meteorological wind towers data summary.

Site No.	Province	Name	Annual wind speed (m/s)		Annual GHI (kWh/m²/day)	
			Towers	Map	Towers	Map
Site 1	Parwan	Jabal Saraj	4.69	4.51	4.19	5.19
Site 2	Balkh	Uljato	6.20	6.51	3.29	4.78
Site 3	Balkh	Sari Tangi	4.73	5.57	3.16	4.78
Site 4	Kabul	Naghlu	5.18	6.71	2.71	5.21
Site 5	Herat	Urdo Khan	5.99	5.93	5.61	5.39
Site 6	Herat	Hotel Safid	9.09	6.77	13.15	5.39

4. Potential of Solar Energy

Afghanistan has an average 300 sunny days per year and located in the region of planet with intense sunshine and clear sky. Fig 3 shows the global solar resource map and its direct normal irradiance in kWh/m2/year. Afghanistan receives the annual average direct normal irradiance more than 1,022 kWh/m2/year. In the south and west of the country, it receives in the range of (1,825 to 2,445) kWh/m2/year that is suitable for CSP (concentrating solar power) technology installation. The solar energy is abundant and available in all part of the country. CSP technologies require more solar radiation than solar PV technologies. According to the NREL's maps for Afghanistan solar resources, it receives the average annual solar global horizontal irradiance in the range of (3.9 to 5.9) kWh/m2/day that is suitable for solar PV installation across the country.

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So far, the renewable energy department has implemented 2,364 solar energy projects in the country with a total capacity of 1.8MW. The whole projects are mini-grids for the lighting of homes, clinics, and schools. Despite huge potential of solar energy in the country, so far there is no any utility-scale grid-connected solar power plant. Except, there is 1MW solar PV and diesel hybrid mini-grid in the city of Bamyan in the central Afghanistan. Moreover, there is a plan for the installation of 10MW grid-connected solar plant in Kandahar city.

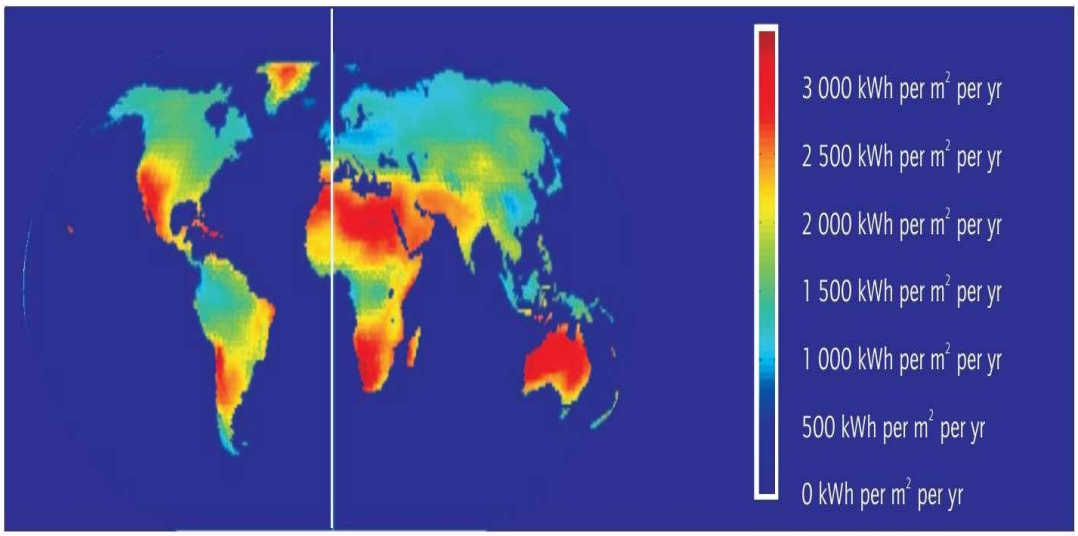

Figure 3: World Solar Resources for CSP Technologies (DNI in kWh/m²/year)

5. Potential of Geothermal Energy

Geothermal energy is heat that is being generated inside the Earth. (Geo meant "earth," and thermal meant "heat".) It has been a renewable resource that can be gathered for human use. Nearly 2,900 kilometers (1,800 miles) beneath the Earth's crust, or surface, is the hottest part of our planet, the core. As small part of the core's heat bring about from the friction and gravitational pull formed when Earth created more than 4 billion years ago. However, the extensive majority of Earth's heat is constantly being generated by the decay of radioactive isotopes, such as potassium 40 and thorium 232. Isotopes are forms of an element that have been different number of neutrons than regular versions of the element's atom. Potassium, for example, has 20 neutrons in its core. Potassium-40, however, has 21 neutrons. As potassium-40 decays, its nucleus changes, emitting huge amounts of energy (radiation). Potassium-40 regularly rots to isotopes of (calcium-40) and (argon-40) radioactive decline is a continual process in the core. Temperatures there surge to more than 5,000° Celsius (about 9,000° Fahrenheit). Heat from the core is continually radiating outward and hot rocks, water, gas, and other geological material. Earth's temperature increases with depth from the surface to the core. This gradually change in temperature is known as the geothermal gradient. In many parts of the world, the geothermal slope is almost 25° C per 1 kilometer of depth (1° F per 77 feet of depth) If underground rock formations heated to about 700-1,300° C (1,300-2,400° F), they can become magma. Magma is liquid (mostly liquefied) rock penetrated by gas and gas bubbles. Magma exists in the mantle and lower crust, and sometimes bubbles to the surfaced as lava. Magma heats closer rocks and underground aquifers. Hot water can be leaked through geysers, warm springs, steam vents, underwater hydrothermal vents, and mud pots. These are all sources of geothermal energy. Their heat can be sized and used straightly for heat, or their steam can be used to come to

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exist electricity. Geothermal energy can be used to heat formation such as buildings, parking site, and sidewalks.

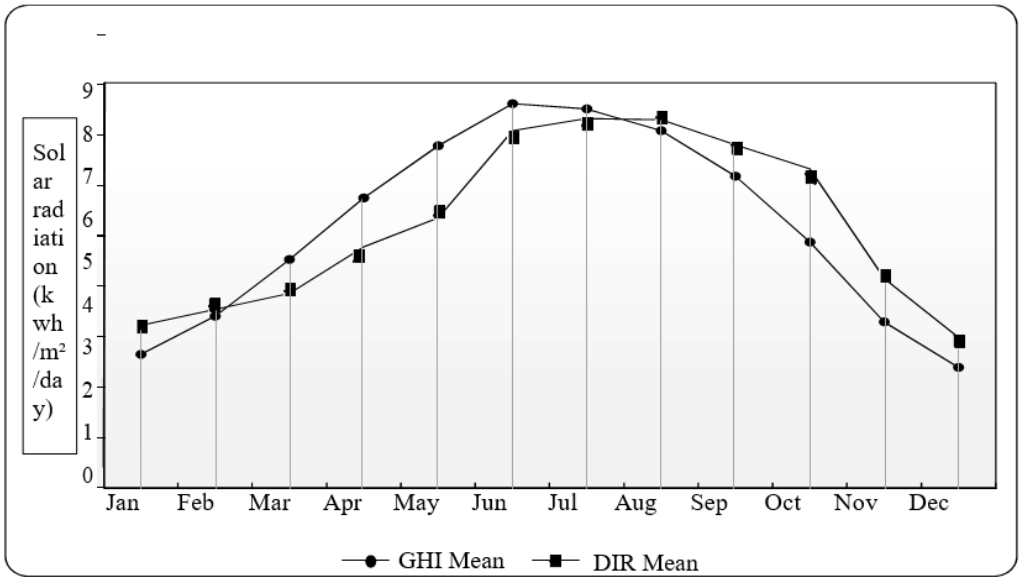

Figure 4: Monthly average solar irradiance for Afghanistan

Many countries have access to the developed methods or principle of tapping into geothermal energy. Different types of geothermal energy are in different parts of the world. In Iceland, abundant sources of hot, easily are accessible underground water make it most possible for most people to depend upon on geothermal sources as a safe, dependable, and cheaper source of energy.

Table 4 explains the field name, location, field type, and a total number of wells in each field that measurement had been carried out.

Table 4: Location, type, and number of wells (data collected) in each oil and gas field.

S. No	Filed Name	Province	Field Type	Total number of wells (data collected)
1	Angut	Sari Pul	Oil	9
2	Khwaja Gogerdak	Jawzjan	Gas	12
3	Yatim Taq	Jawzjan	Gas	11
4	Jangal-e-Kalan	Jawzjan	Gas	3
5	Khwaja Bulan	Jawzjan	Gas	7

6. Analysis

In this paper describes the overview and assessment of Afghanistan Solar, wind and geothermal resources we have huge sunny days nearly 300 days of year in Afghanistan, but

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we can't investment on those sectors we also have 120 wind days in west of country in Herat and Nimruz province the speed of wind in almost 30 up to 40KM/Hour. In coming future about 506MW wind and Solar is can be built by the private sectors in Herat province. Now we have 30MW solar project in Kandahar and 15MW of that is connected with the transmission line for use of customer and wind energy capacity is 300KW only in Herat province.

7. Conclusion

In the following paper deliberate a small detraction of available extensive renewable energies especially wind, solar, and geothermal energy can address the electrical supplies of residential areas, commercial and industrial loads in Afghanistan. All renewable energy development related factors were being considered in this study except of transmission line. Which are not exist. Furthermore, the economics study of solar PV, wind shape and geothermal energy would be measured for further development. Finally, the land that is used for calculated area was only state/governmental property. Which does not require the site comprehensive from private sectors or individual owners.

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