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A REVIEW OF SUSTAINABLE AND RENEWABLE SOURCES OF ENERGY FOR AFGHANISTAN
(TINJAUAN SUMBER ENERGI BERKELANJUTAN DAN TERBARUKAN UNTUK AFGHANISTAN)

Abdul Baser Qasimi[1*], Vahid Isazade[2], Ara Toomanian[2]
[1] *Department of Geography Faculty of Education, Samangan University, Afghanistan.*
[2]*Department of Geographic Information System Faculty of Geography, University of Tehran, Iran.*
*Corresponding Author: qasimi.abdul.a@gmail.com

ABSTRACT
Supplying energy demands in Afghanistan is a serious problem, providing demanded energy for consumption is mostly provided by neighboring countries, especially Iran, Turkmenistan, Uzbekistan, and Tajikistan. Domestic production of energy covers only an only small portion of energy demands in the country. In this regard, the energy supply in this country is extremely vulnerable and indicates non-sustainability. This study was intended to review available conducted research and published articles and reports. the results obtained from these reviews show that the utilization of renewable energy, especially, solar and wind energy, resources in Afghanistan is the only reliable and sustainable solution for the energy problem in this country. The results of the review of the previous research indicate that Afghanistan has great potentials for renewable energy sources. the country has sources of renewable energy, including solar, wind, and geothermal energy.

Keywords: Afghanistan; hydropower; renewable energy; solar energy

ABSTRACT
Penyediaan kebutuhan energi di Afghanistan merupakan masalah serius, penyediaan energi yang dibutuhkan untuk konsumsi sebagian besar disediakan oleh negara-negara tetangga, terutama Iran, Turkmenistan, Uzbekistan, dan Tajikistan. Produksi energi dalam negeri hanya mencakup sebagian kecil dari kebutuhan energi di dalam negeri. Dalam hal ini, pasokan energi di negara ini sangat rentan dan menunjukkan ketidakberlanjutan. Penelitian ini dimaksudkan untuk meninjau penelitian yang dilakukan yang tersedia dan artikel dan laporan yang diterbitkan. hasil yang diperoleh dari tinjauan tersebut menunjukkan bahwa pemanfaatan energi terbarukan, khususnya, energi matahari dan angin, sumber daya di Afghanistan adalah satu-satunya solusi yang andal dan berkelanjutan untuk masalah energi di negara ini. Hasil tinjauan penelitian sebelumnya menunjukkan bahwa Afghanistan memiliki potensi besar untuk sumber energi terbarukan. negara ini memiliki sumber energi terbarukan, termasuk energi matahari, angin, dan panas bumi.

Kata kunci: Afganistan; energi matahari; energi terbarukan; tenaga air

INTRODUCTION

Afghanistan is challenging various disputes on its path of development and reconstruction. The nation would benefit from creating and implementing a sustainable energy plan among all of its other essential requirements (Milbrandt & Overend, 2011). Alternative possibilities, such electricity produced from renewable resources, were taken into consideration by the previous Afghan administration (wind, solar, biomass, geothermal) however most of the strategies were left on the paper because of the systematic corruption and reliance of the constructions budgets on foreign assistance (Milbrandt & Overend, 2011). After three decades of war, with massive environmental and social losses, and Despite decades of United Nations and donor investments totaling hundreds of billions of dollars, more than 25 million Afghans still lack access to electricity to address basic needs and spur economic growth. The majority of these people are rural residents who have little access to stable sources of income, health care, or education (Foster et al., 2012). All of the infrastructure in this country was destroyed prior to 2000 due to wars and internal conflicts, and as a result of the war between the government and the Taliban since 2000 to 2021, infrastructure development in rural areas was not aided by consistent security(Zürcher, 2012).

Due to its effects on socioeconomic progress, electricity has been given significantly higher preference or priority than other sectors since the advent of the new administration in 2001. (Danish et al., 2017). When considering all options from the perspective of economic viability, imports of power were the first option because of the urgent need to address the electricity shortfall in Kabul (Qehaja & Mentis, 2019). Energy imports from four nearby nations—Iran, Uzbekistan, Turkmenistan, and Tajikistan—were estimated to reach 2,250 GWh in 2011. These imports represent 73% of the nation's electrified areas' total energy demand (Danish et al., 2017). After 20 years of investment in the energy sector and expenditure of hundreds of millions of dollars, the electrical energy system for this country is unsustainable, 91 % of the rural population do not have access to electricity (Mehrad, 2021). The major causes of the lack of access to energy in rural areas can be attributed to the absence of a regular and long-term policy, the existence of corruption, and the inadequate energy transmission infrastructure(Marquette, 2011).

Currently, just 30% of Afghan families have access to electricity, according to World Bank reports, the accessibility to electricity was just 8% in 2004, and the growth of access to electricity expose 22% in the past 14 years (Baqir et al., 2021). However, the grid networks and transmission lines for the power plants and distribution are not significantly expanded. The current infrastructure of the power industry is based on internal hydropower, diesel engines, and imported energy (Hakimi et al., 2020). The cost of electricity paid by consumers and householders is exhausting, 0.06 for hydropower to 0.4

dollars for the electricity generated by diesel generators (Danish et al., 2017).

Larger cities especially Kabul suffers heavy air pollution because of the consummation of Solid or fossil fuels for heating and cooking due to inadequacy of electricity or because of the high expanses (Waseq, 2020). Kabul suffers from poor air quality and overcrowding. Kabul, a metropolis of around 6 million people, is one of the world's most polluted cities, along with New Delhi and Beijing. Its infrastructure has been destroyed by four decades of war, which has led to overpopulation and a storm of displaced people (Waseq, 2020).

Sustainable energy resource is closely associated with climate change, agricultural productivity, economic development, and food security. Access to renewable energy is critical to accomplishing sustainable development goals. Indeed, there is a close association between energy inadequacy and poverty indicators like illiteracy, life expectancy, and infant mortality (Ibrahimi et al., 2019). Shifting toward renewable energy sources is accelerated by increasing fossil fuel costs, developing renewable energy technologies, and implementing policies across the world (reflected the real expense and negative impacts of fossil fuels) (Ibrahimi et al., 2019).

The pace of economic and social progress is being seriously hampered by the energy dependability challenge. Simply put, in order to support the nation's economic growth and employment demands, there is an urgent need for dependable, affordable, and sustainable power. (Sediqi et al., 2018). Afghanistan possesses a substantial solar energy potential, which can be considered the most effective alternative for assuring the country's continued access to sustainable power and for strengthening the nation's energy security (Mehrad, 2021). It is estimated that Afghanistan's average solar capability GHI is 6.5 kWh/m2/day, and the country receives 1,022 kWh/m2/year of direct normal irradiance. Afghanistan enjoys 300 days of sunlight per year. Even though the average amount of solar radiation in the northern provinces is only 4.5 kWh/m2/day, Helmand, Kandahar, Farah, and Herat are the provinces that receive considerable amounts of solar radiation.

Lower latitudes in the Northern Hemisphere receive greater solar radiation than higher latitudes; the provinces of Kandahar, Farah, Helmand, and Herat are also located in southern Afghanistan. Additionally, Afghan provinces have a smooth topography compared to others, which increases the suitability of these provinces for establishing solar PV power plants (Dang, 2017). There are massive waste areas with great wind energy potential in Afghanistan. The Renewable Energy Department of MEW estimates the wind's energy potential to be around 67,000 MW (Elliott, 2011), while this potential is estimated at 158,000 MW by NREL (Rezaei et al., 2020). Hydropower is counted as the most favorable long-term resource for power generation in Afghanistan due to the availability of various river networks and positioning

upstream (Danish et al., 2017), (Sediqi et al., 2018). Moreover, Afghanistan has well distributed geothermal fields with great potentialsGeothermal resources in Afghanistan are abundant and can be found in close proximity to major cities, including Kabul, Kandahar, Herat, Jalalabad, Ghazni, Gardez, Khost, and Charikar in the country's east, south, and west (Anwarzai & Nagasa, 2017).

In this paper, we are intended to review the most recent and successful research related to renewable energy potentials, implementations, challenges, opportunities, and solutions exposed by conducted research results and pointed by successful researchers to include specific suggestions for future researchers and implementation sectors.

Status of Energy in Afghanistan

Access to energy is the foundation of socioeconomic progress in every nation. However, barely 30% of the population in Afghanistan has access to power. More than 75 percent of the people live in rural areas, where less than 10 percent have access to electricity and about 35 percent live below the country's absolute poverty level (Ludin, Matayoshi, et al., 2017). In Afghanistan, the urban areas have the most access to grid energy. Most of this supply comes from energy that is imported from other countries. The rest is produced using hydro and thermal (diesel) resources (Bhandari et al., 2015).

According to government statistics, around 20-25 percent of Afghan householders have permanent access to energy, making Afghanistan one of the countries with the lowest access rates in the world. Furthermore, access to power is significantly lower in rural regions (Jahangiri et al., 2019).The energy supply in Afghanistan is not steady and reliable due to disrupted grid networks, conflict, and inadequate investment(Ahady et al., 2020), Despite the fact that Afghanistan's energy demand is rapidly rising owing to variables such as population growth, GDP development, fluctuating energy prices, historical shifts in energy intensity, per capita consumption, domestic energy circumstances, and energy availability (McLellan & Blanchard, 2018).

The country is severely reliant on imports of energy from neighboring countries, and only around 9% of the population has access to intermittent public power. According to Da Afghanistan Breshna Sherkat (DABS), just 22.6 percent of the country's power is produced domestically; the remaining 77.4 percent is imported. Uzbekistan provides 34%, Tajikistan (42%), Iran (8%), and Turkmenistan (16%). Although Uzbekistan is the most important foreign supplier, transmission capacity is limited (Ahady et al., 2020). Figure (1) presents the amount of imported energy from neighboring countries (Ludin et al., 2017).

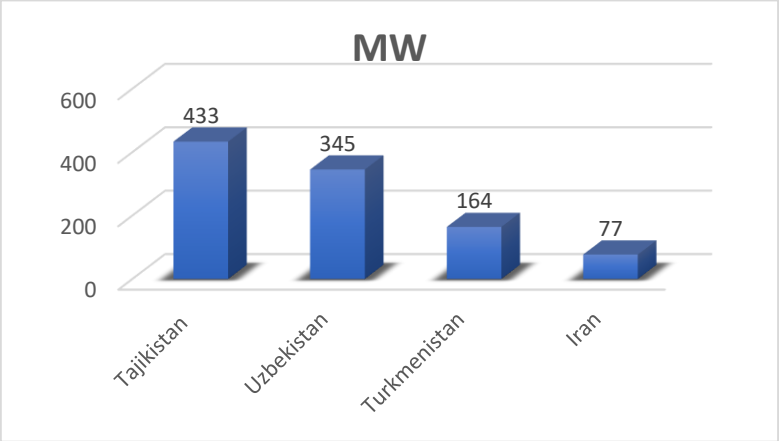

Figure 1. cost of imported energy from neighboring countries in 2017

The country's transmission network is highly fragmented and constructed of independent grid systems that receive power from a number of producing facilities and various importing sources. The power system is divided into four distinct networks: the Herat Zone System, connected to Iran and Turkmenistan; the Northeast Power System (NEPS), connected to Tajikistan and Uzbekistan; and the Southeast Power System (SEPS)

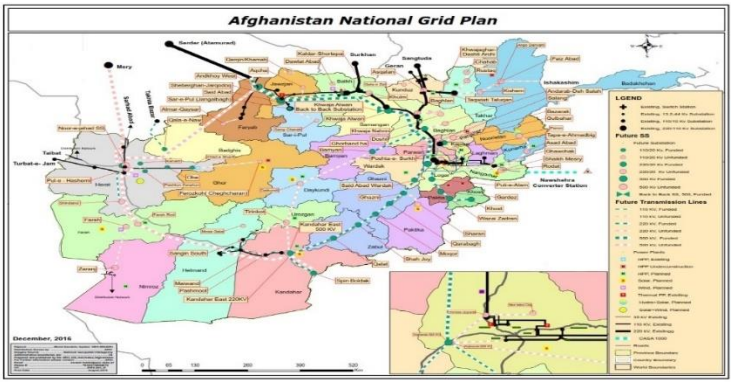

Figure 2. Existing and planned grid system and transmission line for Afghanistan.

The transmission infrastructure in Afghanistan was projected to have a length of roughly 1,905 km in March 2017, with a transformer capacity of around 1,544 MVA for voltages ranging from 110 kV to 220 kV. The voltage levels in the distribution system are 20/15/6 kV, and there are a total of 10 distribution zones. The distribution capacity is roughly 1,155 MVA (Sabella, 2021). Figure 2 shows the current and future grid infrastructure (Islamic Republic of Afghanistan Ministry of Energy and Water RENEWABLE ENERGYPOLICY, 2015).

Potential Resources of Renewable Energy In Afghanistan

The destructive impacts of fossil fuel and nuclear energy on the environment and the inadequacy and unreliability of the existing energy sources force Afghanistan to shift toward clean, renewable, and sustainable energy resources such as wind, solar, and geothermal resources (Nasery et al., 2021). The rural society in Afghanistan plays a key role in the economy and development, the rural area has no access to electricity (Bhandari et al., 2015).

Access to reliable and affordable electrical energy is vital for sustainable development in rural communities and it can play a significant role in reducing poverty (Sadiqi et al., 2012). Fortunately, Afghanistan enjoys an abundance of Renewable Energy Resources (RES), the provinces and remote areas that are improbable to be supplied by a centralized grid has massive Renewable Energy (RE) potential. The utilization of these resources will provide the aid to alleviate future energy supply gaps at a level cost that are both economically and environmentally attractive (Mitkov et al., 2019).

Hydropower

Most of the energy generated in Afghanistan comes from hydro sources(Mesbah et al., 2017). A survey conducted by the United Nations in 1972 and the reports provided by the survey of DABS exposes that the overall hydrological potential of Afghanistan to produce electrical energy is 20000 to 23000 MW, which includes all small, medium, and large hydropower plants (Mesbah et al., 2017), (Slimankhil et al., 2020). Micro-hydropower is the most used and environmentally friendly renewable energy technology in Afghanistan(Sadiqi et al., 2012).

Currently installed hydropower plants can generate 377 MW of energy(Alamy & Sultani, 2021), most of these sites are seasonal and the overall capacity factors for the installed sites are less than 40% (Hallett, 2009). The energy generated by hydropower covers the demands of only 8% of the population in the country (Status et al., 2021). harvesting energy by employing water in Afghanistan is affected by factors such as political conflicts with the neighboring countries, comprehensive water management agreement is crucial for the utilization of the existing potentials(Ahmadzai & McKinna, 2018).

Installed hydropower and generation capacity is presented in table 1. Additionally, smaller hydropower facilities are typically built in rural regions with the intention of producing electricity for neighborhood illumination. The advantages of sustainable energy can be realized with deliberate investments in hydropower. With sufficient hydropower, poverty might be reduced or eradicated by generating jobs, attracting tourists, boosting economic activity, and constructing efficient governmental infrastructure. The groundwater supply may be restored and greenhouse gas emissions could be decreased by building dams. Increasing hydropower

capacity also supports increased biodiversity and a better quality of life (Ludin, Amin, et al., 2017).

Table 1. The potentials of the hydropower based on rivers.

Zone	River	Potential [MW]
Kabul	Kabul	408
	Panjshir	400
	Laghman	44
Panj-Amu	Kunar	1089
	Panj	9050
	Amu	9110
	Kokcha	1927
Northern	Kunduz	50
	Jawzjan	460
	Balkh	300
Hari rod-Murghab	Harirod	102
	Murghab	100
Helmand	Helmand	190
	Farah Rod	80
Total		23310

Solar energy

The generation and distribution of solar energy require various technologies to interface with conventional current energy grids(Modrzejewska-leśniewska, 2012). In 2020, the total global solar energy production was 844.39 TWh while concentrated solar-thermal energy (Sadat & Sabory, 2020) generation was 458.46 TWH, with China, the United States, India, and China as the major producers, the total solar power generated by Afghanistan in 2020, indicates only 40 MWh Afghanistan is a "sunbelt" country (Burns, 2011).

The annual average Global Horizontal Irradiance (GHI) in Afghanistan is 1,935 kWh m^{-2} day^{-1} and the national average seasonal maximum and minimum are 7.84 and 220000MWh solar energy per year(Slimankhil et al., 2020).

Solar energy is deemed to be the most abundant renewable energy source and feasible source for electrifying rural areas(Meisen, 2008). By the inception of reconstruction plans of the government in 2001, the electrification of the rural regions utilizing solar energy was considered as one of the priorities. Conducted research exposed that Afghanistan has high solar energy potential that will exceed its basic need for decades(Haidari, 2020). According

to the forecasted Gross energy demand for Afghanistan in 2032 is 22000 GWh and unless utilizing renewable sources of energy it is impossible to be covered(Nazari, 2017).

The southern regions of the country receive more solar radiation due to the variation in the angle of the incoming sunlight according to latitude, while the northern provinces receive lower radiation. The potential for solar energy is influenced by topography, distance to the electricity transmission grid and distance to the road. The provinces of Farah, Helmand, Herat, Kandahar, and Nimroz expose the highest potential due to their location in lower latitudes and smooth topography, and other provinces show lower potential based on their higher latitudes and complicated topography Fig. 3. The feasible potential based on provinces is provided in the table (1)(Mehrad, 2021).

A large part of the northern, western, and southern regions of Afghanistan are deserts and barren plains with low slopes, the annual average of precipitation is usually low in these areas and has high temperature during the summer, it reaches up 45 degrees Celsius most of the time. Thus, these regions are more feasible for solar Power plants(Alamy & Sultani, 2021).

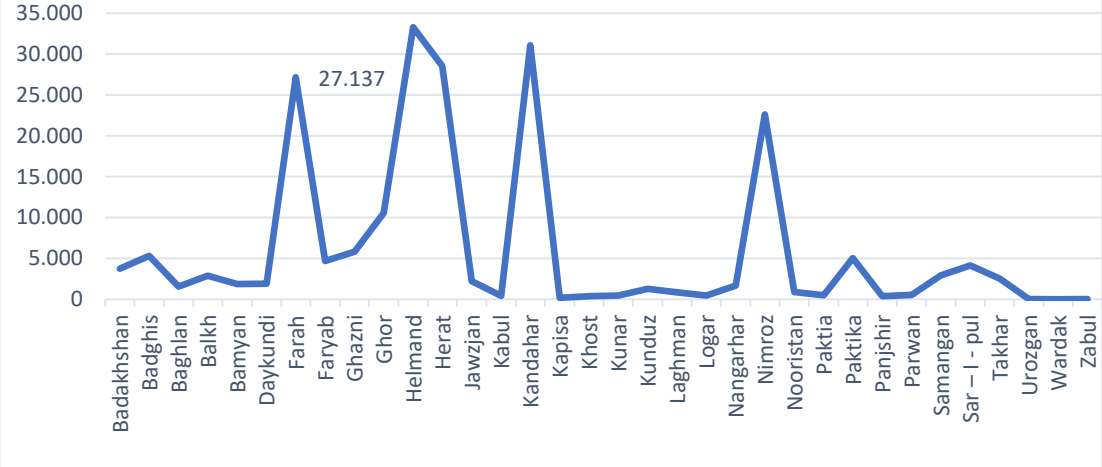

Figure 3. The potentials of solar energy in MWh based on Provinces

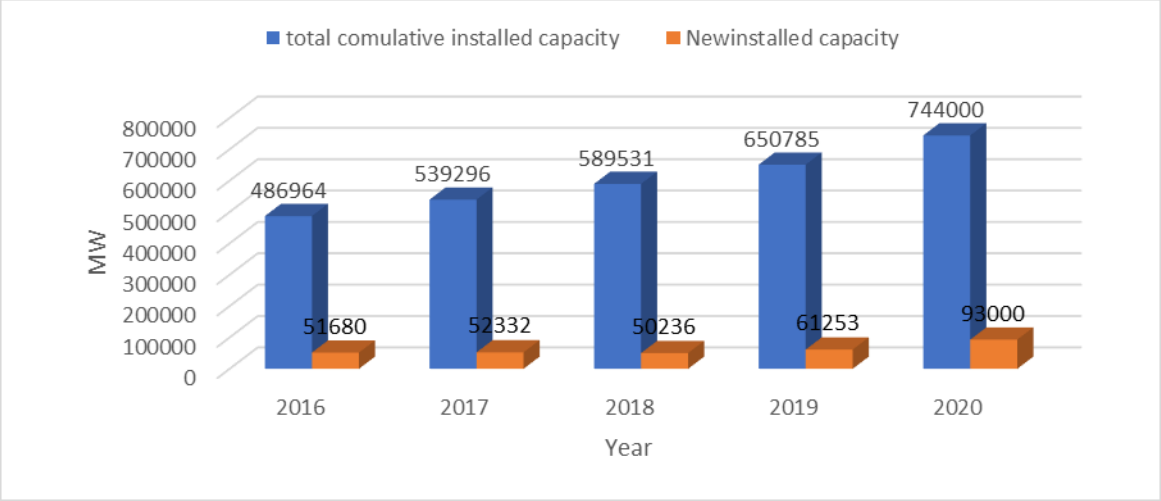

Figure 4. Presents the cumulative and newly installed capacity of wind turbines across the world

Wind Energy

Wind is considered as a reasonable source of energy, according to the WWEA (World Wind Energy Association) the total capacity of produced global wind energy in 2020 reached up to 744 GW and annual newly installed capacity exhibits an annual rate of increase compared to the past years and 2020 shows the highest rate as well(*Statistics - World Wind Energy Association*, 2020,). China is ranked first in producing wind energy and followed by the United States (*World Adds Record New Renewable Energy Capacity in 2020*). Throughout the increase of environmental concerns, the nations are shifting toward clean energy sources and utilizing wind energy potentials.

Afghanistan has great potential for producing wind energy mostly concentrated in the west, southwestern and northwestern regions(Slimankhil et al., 2020). Overall potential estimated by the national energy Department is 158 GW and 67 GWh is considered as feasible potential. Details of wind energy potential are provided in the table (x) (Anwarzai & Nagasaka, 2017).

Table (2). The total potentials of wind energy available in Afghanistan.

Wind Speed	Potential Area (km^2)	Wind energy potential (MW)
6.8-7.3	15193	75970
7.3-7.7	6633	33160
7.7-8.5	6615	33100
> 8.5	3169	15800

Utilizing Wind energy potential is more complicated compared to the solar potential, sand dust storms highly affect even damage the rotors, these

factors can cause high maintenance costs compared to other countries(Modrzejewska-leśniewska, 2012).

Potentials of wind energy for Afghanistan is classified as below according to wind speed:

1. Western provinces, Herat, Badghis, and Nimroz where the wind speed exceeds 27m/s, the turbines with a capacity of 100kw can be utilized in this region.
2. Southern, eastern, and central regions with an average velocity of 9m/s, these regions are reasonable for the turbines with a capacity of higher than 30kw.
3. provinces in the north, northeastern and parts of south regions (Balkh, Badakhshan, Takhar, Baghlan, Kunduz, Laghman, and Jalalabad), wind speed in these regions are lower than 9m/s and suitable to utilize the turbines with the capacity of (1-30kw).

Overall capacity to produce wind energy is assessed at 1kw in each 10 m^2 with an overall capacity of 158 GW(Alamy & Sultani, 2021).

Geothermal and Biomass Potential Energy

Geothermal energy is one of the most reliable and durable renewable energy resources, can be harvested regardless of air condition, and is capable to be utilized to generate power(Mostafaeipour et al., 2020). Geologically, Afghanistan is situated on three tectonic plates which movement and confrontation of these plates result tectonic activities such as hot springs, hydrothermal minerals, volcanoes, and magma rocks(Slimankhil et al., 2020).

Initial studies expose active geothermal systems in Afghanistan mostly located in the main axis of the Hindukush mountains, which runs throughout the Herat fault system(Modrzejewska-leśniewska, 2012), toward the Wakhan corridor in the east. Countless geothermal springs are available at low and medium temperatures.

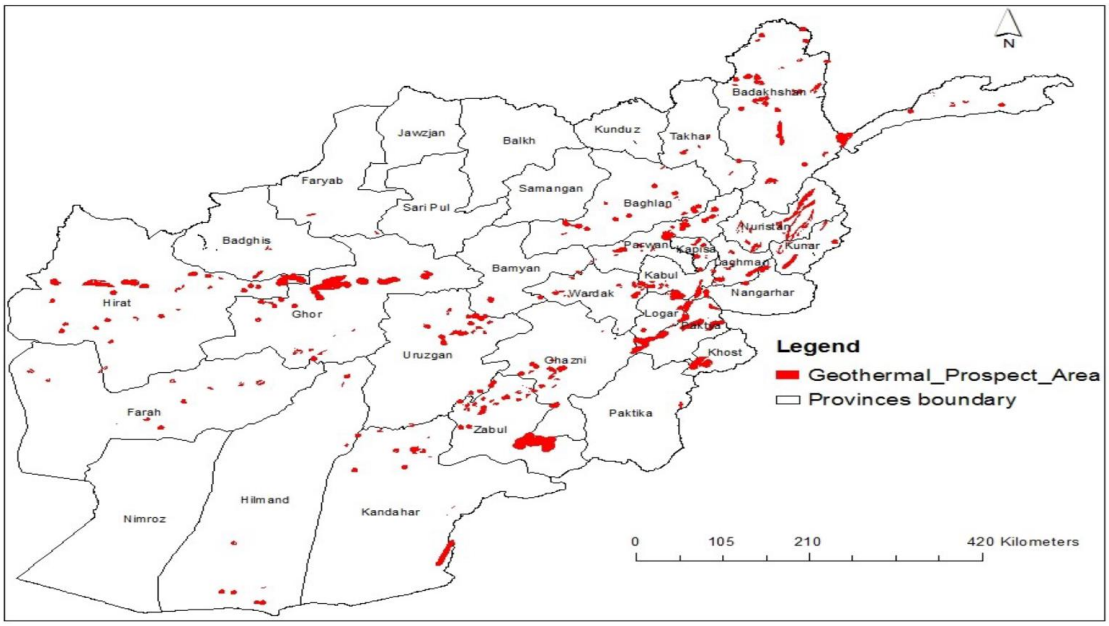

Figure 5. Presents the potential locations of geothermal energy for Afghanistan (Anwarzai & Nagasa, 2017)

CONCLUSION

Access to sustainable energy in Afghanistan is considered one of the major problems in this country, more than 90% of people in rural areas do not have access to electricity. According to the results of this review, the electricity demands in Afghanistan are supplied by imported energy from neighboring countries. According to the results of reviewing the papers published since 2000, there are two major problems related to supplying demanded energy in Afghanistan. (a). Due to the lack of refinery infrastructure, Afghanistan is not capable to utilize its available oil resources to produce demanded energy. (b). The transmission network in this country is not capable to provide accessibility of energy for all regions of this country, especially for remote villages and districts.

However, employing renewable energy sources is the only way to provide a comprehensive and sustainable energy supply across the country. According to the findings of this review, Afghanistan has massive potentials for renewable energy, this country has the capability of producing 23310 MWh hydropower, 220000 MWh of Solar energy, 158 GWh of wind energy, and extensive sources of geothermal and biomass. Utilizing renewable energy will provide reliable and sustainable source energy for this country.

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