International Journal of Innovative Research and Scientific Studies, 4(2) 2021, pages: 126-132

ISSN: 2617-6548

URL: www.ijirss.com

Analysis of the Potential for of Floating Solar Panels on Naghlo Hydropower Dam

Laila Zareef[1*], Marzia Jalali[2], Sayed Moqeem Sadat[3]

[1]*National Water Affairs Regulation Authority, Kunduz, Afghanistan*
[2]*Islamic Azad University, Mashhad, Iran.*
[3]*National Water Affairs Regulation Authority, Kabul, Afghanistan.*

*Corresponding author: Laila Zareef (*zareeflaila@gmail.com*)

Abstract

The water and energy challenges have become a big concern in Afghanistan that need to be addressed cooperatively. One of the challenges in the country is electricity generation, and a small part of it is produced in the country, so there are a huge burden and cost to meet the remaining electricity need. Over years and without sustainable management almost all of the dams in Afghanistan lost their effective life due to reservoir sedimentation that led to the reduced reliability of water and power supply. On the other hand, Global warming and high temperature have a direct impact on the number of water sources. Since Afghanistan is located in an Arid to a semi-arid climate that is characterized by the high value of annual evaporation where the precipitation is less than annual evaporation, besides other forms of losses, its surface water is lost through evaporation. On the other hand, one of the challenges in the country is electricity generation, and a small part of it is produced in the country, so there are a huge burden and cost to meet the remaining electricity needs.One of the approaches that can meet both challenges simultaneously is the use of floating solar panels. It has significant advantages over the ground-based type of solar panels. These benefits include reducing water evaporation, improving water quality by reducing the growth of algae, and high solar panel performance. This paper aims at illustrating the potential for use of floating solar panels to generate power and the impact of floating solar panels installation on preventing surface water evaporation on Naghlo Dam.

Keywords: Floating Solar Panels, Evaporation, Naghlo Dam, Electricity Generation.

DOI: 10.53894/ijirss.v4i2.66
Funding: This study received no specific financial support.
History: Received: 8 January 2021/**Revised:** 18 February 2021/**Accepted:** 16 March 2021/**Published:** 30 March 2021

Acknowledgement: Authors would like to express their deepest appreciation to Mohammad Fereshtehpour, Postdoctoral researcher, and lecturer at the Ferdowsi University of Mashhad, Mashhad, Iran for providing invaluable guidance throughout this research. It was a great privilege and honour to work and study under his guidance. Also, Authors would like to thank Hameedullah Zaheb who helped me in providing data for the paper. They would like to thank the co-authors of the paper for their contribution and supports. They wish to thank my parents and friends for their support or attention who inspired them to go their own way.
Competing Interests: The authors declare that they have no conflict of interests.
Transparency: The authors confirm that the manuscript is an honest, accurate, and transparent account of the study was reported; that no vital features of the study have been omitted; and that any discrepancies from the study as planned have been explained.
Ethical: This study follows all ethical practices during writing.

1. Introduction

Water resources management is an important action in the field of development and self-sufficiency of the country. Afghanistan is one of the richest countries in the region in terms of water resources, but so far this valuable resource has not been used to develop and improve the country's economy.

The capacity of water resource is estimated to be 75 billion cubic meters, 55 billion cubic meters of which make up the surface waters, and the remaining lies underground [1] . Studies show that the amount of surface flow in the different rivers of Afghanistan has decreased from 65% to 40% of the annual flow, and in general, in the country, there is a 50% decrease in the amount of freshwater [2].

Afghanistan has an arid to semi-arid climate, which makes the country more sensitive to water losses due to evaporation because the rate of evaporation in such conditions is very high [3]. In Kabul basin from 1959-1971 the average monthly evaporation rate was 133 mm and between 1957 to 1977 the annual precipitation was 330mm/year which shows that the evaporation rates are high relative to precipitation in Kabul basin [3]. High evaporation rate causes the water in the lake, canal, dam, reservoir, and river basin to vaporize into the atmosphere [4]. So correct identification of the of water losses that occur through evaporation and its prevention is an important action in the field of accurate management of water resources in the country.

Afghanistan is a country of 34.6 million people [5].70% of the population in the country has no access to electricity and the annual consumption of electricity is 100 kilowatt-hour (KWH) per person [6]. Furthermore, electricity is one of the Afghan people's most pressing needs. Most of the country's electricity is now imported, but a small amount is produced in the country. Afghanistan annually imports at least $280 million worth of electricity from Iran, Uzbekistan, Tajikistan, and Turkmenistan [7]. As shown in Figure 1 the amount of imported power covers only 80% of the need, and the shortage is supplied by internal power generation [8].

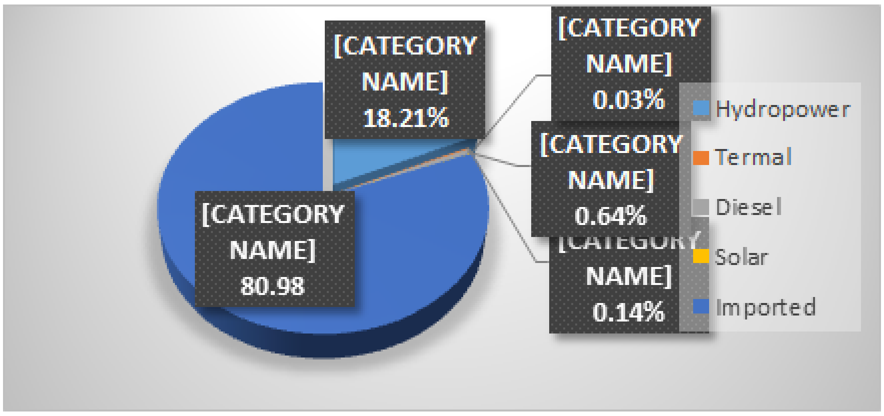


Figure-1.
The percentage of imported to and generated power inside Afghanistan in 2018 [8].

Over the years and without long term maintenance, due to reservoir sedimentation, almost all of the Afghanistan's dams have reached the end of their useful lives, resulting in lower water and power supply [8]. As an example the Naghlo dam has a sediment discharge system, but the system has been inactive for thirty years and no sediment has been discharged as a result Sediment in the reservoir of the dam reached its critical state. Sand and debris have taken up 40% of the Naghlo dam reservoir [9].

Since Afghanistan has 300 sunny days each year, its average solar potential is estimated to be 6.5 KWh per m2 per day [10]. The annual potential of power generation by Photovoltaic solar in Afghanistan is 140,982 GWh studied by Anwarzai and Nagasaka in 2016 [11]. In 2018 1347.7-megawatt-hours of electricity in the country has been generated by solar panels, so the use of solar panels in Afghanistan to generate electricity is not a new concept [8].

In the past, solar panels as renewable energy and hydropower plants were developed separately but now their combination is used to generate electricity. For the top 20 hydropower plants it has been shown that covering 10% of hydropower plan basin surface increases hydropower plan energy generation capacity by 65% [12] The use of solar panels on water surfaces is one of the new solutions in the world, which is growing rapidly due to its greater efficiency and benefits. Agostinelli [13]. Floating solar panels are 16 percent more efficient due to the temperature regulation effect of the water [14]. Today, there are more than 300 floating solar installations worldwide. Although the installation cost of floating solar panels is about 20 to 25 percent higher than the type that is installed on the floor and roof, other benefits are compelling enough to invest in, and over time can cover all costs [13].

This paper aims to study the evaporation reduction and electricity generation potential of floating PV solar panels on Naghlo Dam in the Surobi district of Kabul province as an integrated solution to overcome both problems.

2. Methodology

Naghlo is the biggest hydropower dam in Afghanistan located in 34°38′28″N 69°43′01″E on the Kabul River in Surobi district of Kabul Afghanistan. As shown in Figure 2 provided by Global Energy Conservation, the total area for the dam reservoir is 13.2 km2. Naghlo Dam has a normal elevation of 1190 m with 61 m of hydraulic head and 110 m high [15].

The design capacity of the dam is 100 MWh and supplies electricity for about 100,000 households [16]. The average temperature of the district is 17.9 °C with an average annual rainfall of 348 mm, so there is not much rainfall in Surobi throughout the year [17]. The average annual solar resource in Surobi district is high with an annual average of about 5.4 kWh/m2/day with the highest during summer 7-7.5 kWh/m2/day [17]. To examine the power generation capacity and surface water evaporation reduction of floating solar panels on Naghlo Dam a calculation was made to study the surface water evaporation rate in Surobi district and the result was then used to calculate evaporation prevention rate of surface water by applying floating PV solar panels, and power generation capacity of these PV panels. This study also investigated cost saving by reducing the amount of importing power to the country.

2.1. Evaporation Estimation

Evaporation is part of the hydrologic cycle which is affected by metrological factors like temperature, wind, atmospheric pressure. Penman's equation, which is based on wind direction, temperature, and saturated vapour pressure, is one of the techniques used to calculate surface water evaporation [18]. A simplified version of the Penman equation using routine weather data for calculating evaporation rate is described by the following equation: [19].

$$E_0 \approx 0.051(1-\alpha)\times R_S \times \sqrt{T+9.5} - 2.4\,(\frac{R_s}{R_A})2 + 0.052\times(T+20)(1-\frac{RH}{100})\times(a_u - 0.38 + 0.54u) \quad (1)$$

E0 is the average daily evaporation from the free water surface (mm/day) at sea level (z=0). is albedo (Albedo is the ratio of amount of solar radiation reflected by a surface or body) 0f water surface assumed to be 0.08 [18]. Rs is solar irradiance on the reservoir surface in an hour for an average day, calculated as follow:

$$R_s = R_A \times (0.5 + 0.25\frac{n}{N}) \quad (2)$$

ϕ is geographic width of the selected location, ¡ is the ordinal number of the month, for the selected month n and N are the average and a maximum number of sunny hours that can be calculated by the given equation:

$$N \approx 4 \times \phi \times \sin(0.53i - 1.65) + 12 \quad (3)$$

RA is the solar irradiance on the surface of the atmosphere calculated as follow:

$$R_A = 3N\sin(0.131N - 0.95\phi) \qquad |\phi| \rangle \frac{23.5\pi}{180} \quad (4)$$

$$R_A = 118N^{0.2}\sin(0.131N - 0.2\phi) \qquad |\phi| \langle \frac{23.5\pi}{180} \quad (5)$$

T is the average temperature C° for each month:

$$T = \frac{T_{\max} + T_{\min}}{2} \quad (6)$$

RH is the relative humidity and u is the average wind speed in (m/s) 2 m above the water surface.

Because the above equation is for sea level to adjust it for water surface at higher elevations (z) the following equation is suggested:

$$E = E_0 + 0.00012 \times z \quad (7)$$

The daily total evaporation of water can be calculated in equation (8).

$$V(m^3/day) = E(m/day) \times A_{reservoir}(m^2) \quad (8)$$

2.2. Conservation of water:

Amount of water conserved by the installation of floating PV panels

$$\Delta V(m^3/day) = k \times E(m/day) \times A_{CA}(m^2) \quad (9)$$

K is a reduction coefficient that is less than 1 because the reduction of evaporating loss is not 100 percent.

2.2.1. Calculation for the rate of evaporation and water conservation for the Naghlo Dam:

There is a great potential for the advancement of PV floating solar panels framework in saving water. The total area for the dam reservoir as shown in Figure 2 provided by Global Energy Conservation, is 13.2 km2 [15]. We considered 0.25%, 0.5%, 1%, 3%, 5% and 10% of the total area to be covered by floating PV solar panels and the evaporation reduction efficiency is 30% [20]. Based on the given equations for the calculation of evaporation rate and conserved water, and the average data are shown in Table 1 the calculation was made. The wind velocity and temperature are particularly for Surobi District but due to lack of data for Surobi district, we have taken the sunny hours and humidity of Kabul province. In calculations, we assumed that the wind is blowing 2 meters above the water surface and the height of the surface of water equal to normal elevation plus half of the dam height.

Figure-2.
Surface Area of Naghlo Dam reservoir [15]

Table-1.
Data for calculation of surface water evaporation rate in Surobi district [17, 21, 22]

Month	Jun	Feb	Mar	April	may	June	July	Aug	Sep	Oct	Nov	Dec
T_{max} (C°)	11.3	13.8	19	10.9	29.6	36.1	36.4	34.8	32	26.5	20	13.1
T_{min} (C°)	-0.5	2.6	6.7	22.8	15.6	21.2	23.4	22.4	17.6	11.3	4.9	0.3
T_{avg} (C°)	5.4	8.2	13	16.9	22.6	28.7	29.9	28.6	24.8	18.9	12	6.7
RH (%)	0.68	0.7	0.7	0.6	0.48	0.35	0.39	0.4	0.4	0.42	0.5	0.6
n (day)	5.5	6.4	6.5	7.8	9.75	11.7	11.3	11.1	10.1	9.1	8.1	5.9
v2 (m/s)	7	6	5.1	6	5	8.8	8	5.8	4.1	2.8	2.3	3

2.3. Electricity generation:

The energy generation capacity of Floating PV solar panels can be estimated with the following equation, in which is mean insolation in KW/m2/day, is the area covered by Floating PV solar panels and is the efficiency of the system [18].

$$W = \bar{I} \times A \times \eta \qquad (10)$$

The efficiency of the system consistes of three efficiencies, is the efficiency for type or model of the PV panel (preferred monocrystalline panels and adapted average value for the model efficiency is 17%). is the conservation efficiency of the panels and is the efficiency of the inverter considered to be 90% adapted from Vignola, et al. [23].

$$\eta = \eta_{module} \times \eta_{temp} \times \eta_{invertor} \qquad (11)$$

Equation.12 is a function of nominal operating cell temperature (NOCT) for most of the panels the value is 45 ◦C [18] is the ambient air temperature assumed equal to the temperature of the dam reservoir area (=17 ◦C) based on [18].

, and I is the average monthly solar irradiance. Figure 3 shows the solar irradiance of Kabul province [24]. Equation.13 is used to calculate the conservation efficiency of the PV panels. in Equation.13 is the standard efficiency of solar panels under 20 ◦C, the standard efficiency of monocrystalline panels commercially available in Afghanistan is 14%-20% [25] and we considered the optimal value of 17%.

$$T_{panel} = T_{amb} + \left(\frac{NOTC - 20^o}{0.8}\right) \times I \qquad (12)$$

$$\eta_{temp} = \eta_{stc} \times (1 - 0.005 \times (T_{panel} - 25^o)) \qquad (13)$$

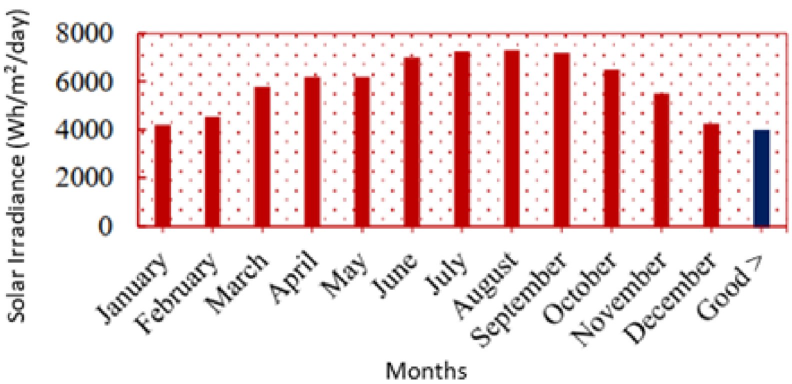


Figure-3.
Average monthly irradiance of Kabul province [24].

3. Results and Discussion

3.1. Evaporation rate and water conservation

Figures 4 and Figure 5 show the daily and monthly evaporation rates of surface water in the Surobi district of Kabul, Afghanistan.

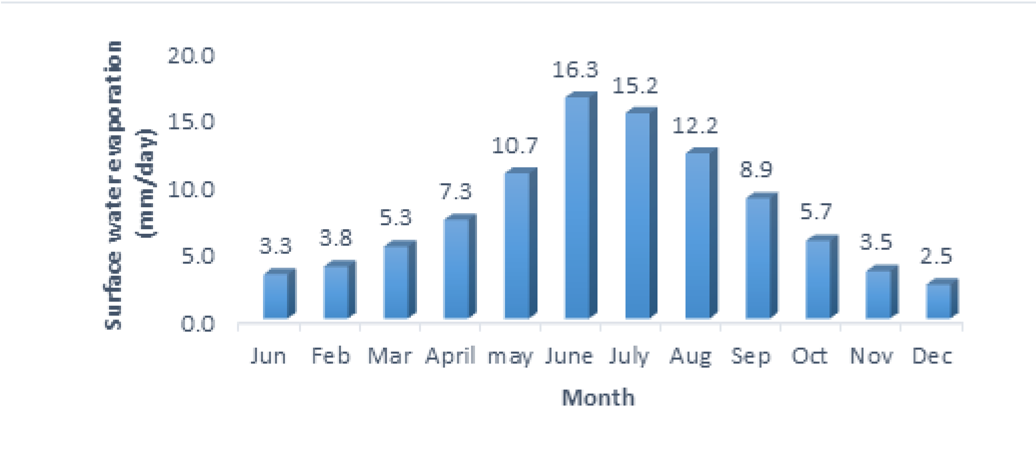


Figure-4.
Average daily evaporation from the free surface of the water in the Surobi district.

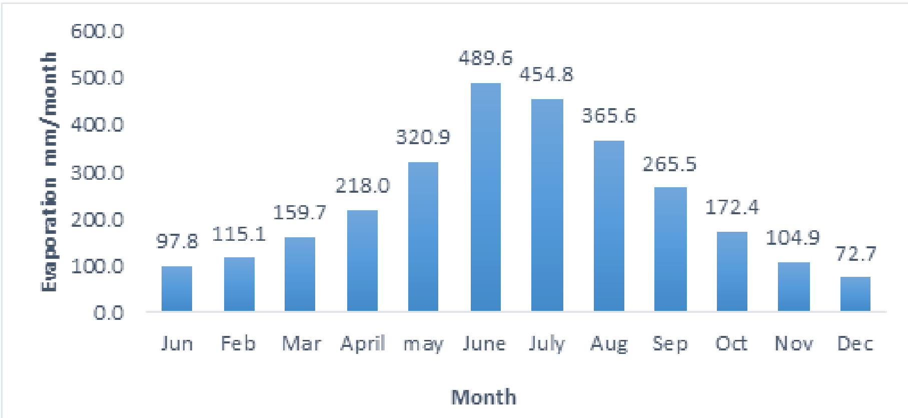


Figure-5.
Average monthly evaporation from the free surface of the water in Surobi district

Based on the calculation performed it can be concluded that the evaporation rate is the highest in June month with 11.7 sunshine hours and it is the lowest in the winter session in December month. The total annual evaporation of surface water in the Surobi district of Kabul province is 2839mm/year and Annually, an average of 34.5x106m3 of water evaporates from the reservoir of the Naghlo dam.

Figure 6 shows the annual conservation rate of surface water from evaporation for different coverage percentage, based on 30% evaporation reduction efficiency of floating PV panels.

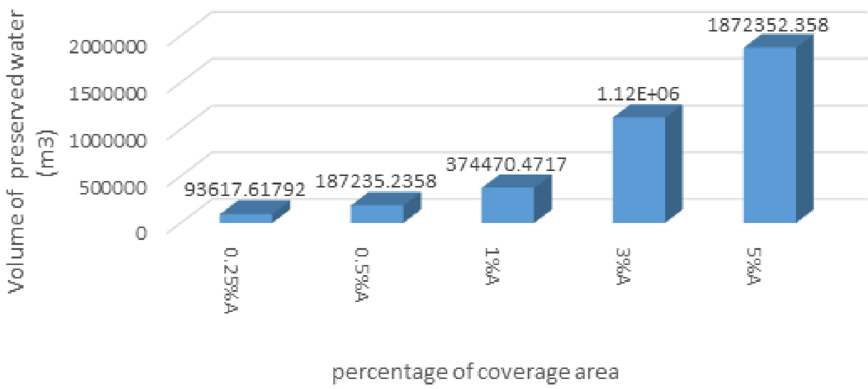
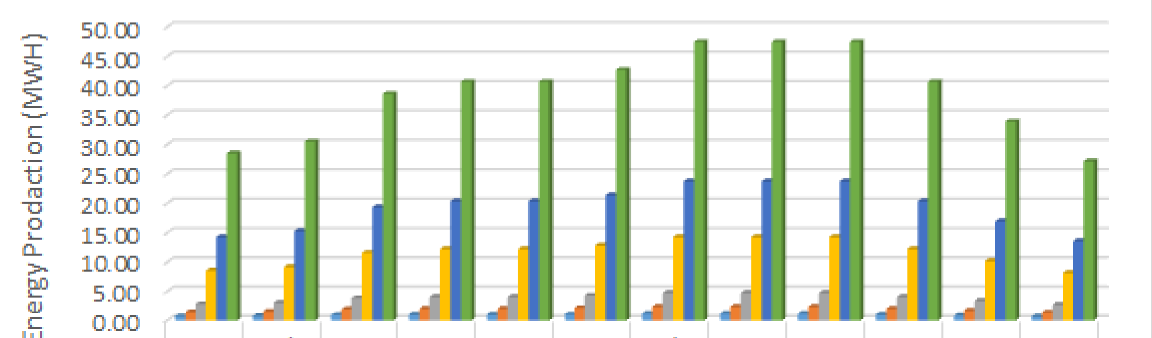


Figure-6.
Annual conservation rate of surface water from

3.2. Energy generation capacity

Figures 7 and Figure 8 show in MWH the monthly and annual energy generation capacity of floating PV panels system on Naghlo dam for 0.25%, 0.5%, 1%, 3%, 5%, and 10% of the total surface area of dam reservoir covered with PV panels.



	Jun	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec
0.25%	0.71	0.76	0.97	1.02	1.02	1.07	1.19	1.19	1.19	1.02	0.85	0.68
0.50%	1.42	1.53	1.93	2.03	2.03	2.14	2.37	2.37	2.37	2.03	1.69	1.36
1%	2.85	3.05	3.86	4.07	4.07	4.27	4.75	4.75	4.75	4.07	3.39	2.71
3%	8.54	9.15	11.59	12.20	12.20	12.81	14.24	14.24	14.24	12.20	10.17	8.13
5%	14.2	15.3	19.3	20.3	20.3	21.4	23.7	23.7	23.7	20.3	16.9	13.6
10%	28.5	30.5	38.6	40.7	40.7	42[illegible]	[illegible]7.5	47.5	47.5	40.7	33.9	27.1

Figure-7.
Monthly energy generation capacity of floating PV panels system on Naghlo dam

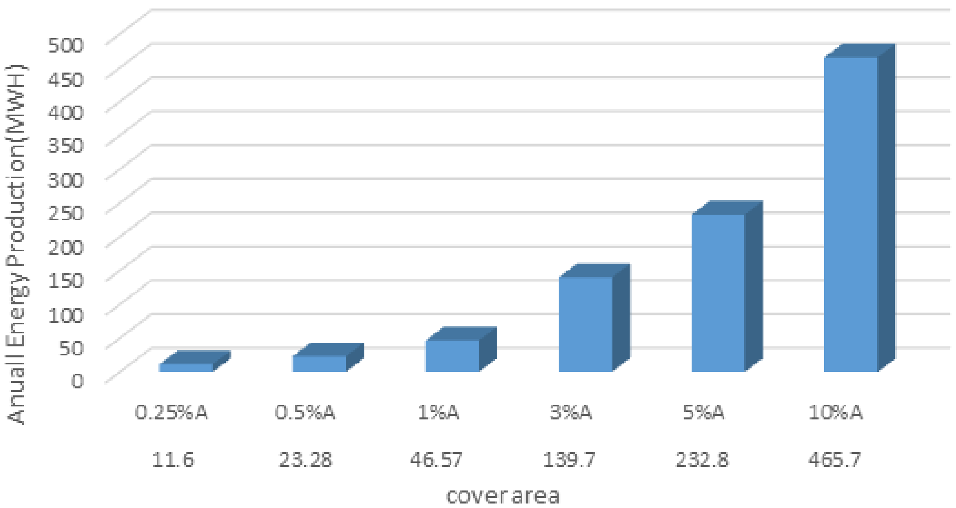


Figure-8.
Annual energy generation capacity of floating PV panels system on Naghlo dam.

Based on the calculation for all the mentioned coverage percentage the biggest production will be achieved in July, August, and September, and in these months the solar insolation has the highest amount of about 7KWH/m2/day and the smallest production will be achieved in December month in which the solar insolation is 4KWH/ m2/day. Annual generated electricity resulted from 3% coverage is 139.7 MWh more than the energy generation capacity of the Naghlo hydropower dam which is 100MWH.

4. Conclusion

This paper studied the evaporation reduction and energy generation capacity of floating PV solar panels on the Naghlo hydropower dam located in the Surobi district of Kabul, Afghanistan. The specific conclusions are summarized below:

- With 55 rainy days the evaporation rates are high relative to precipitation in Surobi district.
- Due to arid and semi-arid climate the annual surface water evaporation rate in the Surobi district is 2839mm/year.
- Based on the annual evaporation rate, 34.5x106m3 of the water evaporates each year from the reservoir of Naghlo dam.

- 3% covering of the dam reservoir generates 139.7 MW Hof energy which is 39.7 MWH more energy than the total generation capacity of Naghlo hydropower dam.
- Installation of solar on the surface of water in dam reservoir can boost the capacity factor of the Naghlo dam to 100%
- This study found if we cover 10% of the Naghlo dam's reservoir with PV panels, it can generate 467.7 MWH of energy.
- In calculation to have a more realistic result, we considered the minimum value of the efficiencies.
- The consumption of electricity varies from province to province in Afghanistan. For example, in Kabul annual consumption of electricity is 3000KHW per household, and for Laghman which is located next to Surobi province this rate decrease to 551KWH per household per year [26]. If we allocate 46.5MWH of energy which can be generated by floating PV solar panels with 1% of the coverage area to the Kabul in can provide electricity for 15333 households with annual consumption of 3000KWH, and if we allocate this amount to the Laghman province it can provide the demand of 83448 households.
- The installation of floating solar panels on Naghlo Dam is more effective in terms of cost-saving because both transmission and distribution networks are already available.

References

[1] M. Saffi and A. Kohistani, "Water resources potential, quality problem challenges and solution in Afghanistan," *DACAAR. P*, vol. 17, 2013.

[2] P. M. Azizi, *Special lecture on water resources in Afghanistan*. Japan: Lecture at Tskuba University, 2007.

[3] T. Tunnemeier and G. Houben, "Hydrogeology of the Kabul river basin, Part 1, Geology, aquifer characteristics, climate and hydrology," *Federal Institute for Geoscinences and Natural Resources (BGR)*, vol. 30655, 2005.

[4] Z. M. Yaseen, A. M. Al-Juboori, U. Beyaztas, N. Al-Ansari, K.-W. Chau, C. Qi, M. Ali, S. Q. Salih, and S. Shahid, "Prediction of evaporation in arid and semi-arid regions: A comparative study using different machine learning models," *Engineering Applications of Computational Fluid Mechanics*, vol. 14, pp. 70-89, 2020.

[5] WHO, "Afghanistan," 2016.

[6] A. Mohsin and B. David, "Power sector reform in Afghanistan," *Energy Policy Journal*, vol. 123, pp. 72-82, 2018. Available at: https://doi.org/10.1016/j.enpol.2018.08.010.

[7] Z. Jahanmal, "Afghanistan annually Pays $280M for imported power," 30 8 2020. Retrieved from: https://tolonews.com/business/afghanistan-annually-pays-280m-imported-power," 2020.

[8] MEW, *Anuall report*. Kabul: Ministry of Energy and Water, 2018.

[9] A. Khalid, "8-subh," 4 7," 2018.

[10] World Bank, "Afghanistan renewable energy development issues and options," 26 6 2018. Retrieved from: http://documents1.worldbank.org/curated/en/352991530527393098/pdf/Afghanistan-Renewable-Energy-Development-Issues-and-Options.pdf.," 2018.

[11] M. A. Anwarzai and K. Nagasaka, "Utility-scale implementable potential of wind and solar energies for Afghanistan using GIS multi-criteria decision analysis," *Renewable and Sustainable Energy Reviews*, vol. 71, pp. 150-160, 2017. Available at: https://doi.org/10.1016/j.rser.2016.12.048.

[12] R. Cazzaniga, M. Rosa-Clot, P. Rosa-Clot, and G. M. Tina, "Integration of PV floating with hydroelectric power plants," *Heliyon*, vol. 5, p. e01918, 2019.

[13] G. Agostinelli, "Floating solar photovoltaic on The Rise," 5 2020. Retrieved from: https://www.ifc.org/wps/wcm/connect/6ef92aa8-bf29-4c43-8edc-a0f7555e6a5d/IFC-EnergyNotes-FloatingSolar_WEB.pdf?MOD=AJPERES&CVID=n8KDCtS," 2020.

[14] R. Chandran, "Why floating solar panels are on the rise," in *World Economic Forum. Retrieved May*, 2019, p. 2019.

[15] R. Gupta, "Naghlo dam hydroelectric power plant Afghanistan. Retrieved: http://globalenergyobservatory.org/geoid/40534," 2010.

[16] World Bank, "Naghlo hydropower rehabilitation project-phase," vol. 1, 2015.

[17] S. Ahmadzai and Z. Paiman, *Naghlu solar power project (SPP) initial environmental examination*. Kabul: Da Afghanistan Breshna Sherkat (DABS), 2017.

[18] V. Durkovi and Ž. Đuriši, "Analysis of the potential for use of floating PV power plant on the Skadar Lake for Electricity Supply of Aluminium Plant in Montenegro," *Ennergies*, vol. 29, 2017.

[19] M. Fereshtehpour, R. J. Sabbaghian, A. Farrokhi, E. B. Jovein, and E. E. Sarindizaj, "Evaluation of factors governing the use of floating solar system: A study on Iran's important water infrastructures," *Renewable Energy*, vol. 171, pp. 1171-1187, 2021. Available at: https://doi.org/10.1016/j.renene.2020.12.005.

[20] G. K. X. Melvin, *Experimental study of the effect of floating solar panels on reducing evaporation in Singapore reservoirs*: National University of Singapore, 2015.

[21] WorldData.info, "Climate for Kabul " n.d.

[22] M. A. Anwarzai, *Research and analysis of Afghanistan's wind, solar, and geothermal resources potential*. Tokyo, 2018.

[23] F. Vignola, F. Mavromatakis, and J. Krumsick, "Performance of PV inverters," in *Proc. of the 37th ASES Annual Conference, San Diego, CA*, 2008.

[24] M. F. Kohistani, N. R. Sabory, A. K. Zarabie, and M. Ahmadi, "A case study of an educational building transformation to renewable energy," *Repa Proceeding Series*, vol. 1, pp. 77-88, 2020. Available at: https://doi.org/10.37357/1068/sodc2019.1.1.10.

[25] ADB, "Ministry of Energy and Water renewable energy roadmap for Afghanistan RER2032," 2017.

[26] A. Korkovelos, M. Bazilian, D. Mentis, and M. Howells, "A GIS approach to planning electrification in Afghanistan," 2017.