Technical and Economic Assessment of the Use of an Autonomous Photoelectric Water Lift Installation in the Karakum Desert

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Abstract: One of the urgent problems of Turkmenistan is the development of desert territories, which occupies 80%. The task of scientific research is to analyze the problems of energy supply and water supply for the development of the desert and the desertification of this territory. One of the priority energy supply is the use of renewable energy sources, water supply, the use of groundwater. The article considers the eco-energy resources and potentials of solar energy for lifting water from the depths, using technical and economic methods to evaluate capital investments, investment costs and energy efficiency of solar photovoltaic water lifting stations in the Karakum Desert. The given methodology for technical and economic calculations, capital investments, investment costs and evaluation of the effectiveness of operational parameters for use in transhumance will be useful in the preparation of a feasibility study (feasibility study). On the basis of solar - energy resources, calculate, draw up an energy map of the rise of water from the depth of occurrence and evaluate the technical and economic indicators for the development of the Karakum desert and the development of transhumance.

Keywords: Map of energy and water supply, Energy efficiency, Solar water lift, Groundwater, Development of the Karakum desert, Development of distant pasture livestock breeding, Turkmenistan.

THE URGENCY OF THE PROBLEM

The development of the desert zone of the Karakum, which occupies 80% of the country's land resources, is one of the urgent problems of the sustainable development of Turkmenistan.

In sparsely populated remote desert areas for energy and water supply, a large amount of water and various types of fossil fuels are annually imported. In this regard, transportation costs for water and fuel are increasing. This, in turn, leads to large financial costs, untimely delivery of water and fuel endangers the life of people.

Using innovative scientific and technical developments, the issues of energy and water supply in life can be partially solved using renewable energy sources (RES).

Turkmenistan has significant RES resources according to the results obtained in solar energy, the technical potential of low-grade solar energy in Turkmenistan is equivalent to 1.4 10^9 tce. tons per year [2, 3, 5, 7-14].

The issue of watering in life is not sufficiently studied due to the lack of specific data on groundwater. Therefore, they were not sufficiently evaluated and calculated the technical, economic and environmental characteristics of the use of solar power plants in the desert zone of the Karakum for use in the life safety of distant pastures in the desert.

The purpose of the scientific work is to analyze the problems of energy supply using solar energy installations for the life safety of water supply using the groundwater of the Karakum desert and, on their basis, calculate, draw up an energy map of the rise of water from the depth of occurrence and evaluate the technical and economic indicators for the development of transhumance animal husbandry.

The scientific novelty of the work is the development, creation of a geoinformation map for life safety and the placement of solar energy water-lifting installations, according to the power of the generated energy, depending on the depth of the wells in the pasture areas of the Karakum. According to the modern methodology, the technical and economic characteristics of capital investments, investment costs are calculated, and the effectiveness of operational parameters for use in transhumance is estimated.

1. TECHNICAL AND ECONOMIC ASSESSMENT OF THE USE OF AN AUTONOMOUS PHOTOVOLTAIC WATER-LIFTING INSTALLATION

Economic efficiency of photovoltaic installations, their importance for the national economy and ecology of Turkmenistan. Issues of

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converting solar energy into electrical energy, calculations of the power of the installation required for lifting water from wells, efficiency from the introduction of SFVU and the cost of renewable energy in Turkmenistan. The operation of pumps is characterized by the volume of water supply, suction height, pressure, power and efficiency, which are usually indicated in the passport data of the pump manufacturer. On the territory of Turkmenistan there are wells of various depths and debits. Based on these obtained data, it is necessary to select the appropriate pump. For this purpose, calculations were carried out and a graph of the dependence of the pump load power on the head at various capacities was plotted (See Figure **1**).

To determine the capacity of the SFVU, it is necessary to determine the required capacity for water lifting for each well in the country, and this requires data on the depth and flow rate of all wells. The paper gives the characteristics of wells in terms of debit and depth.

Having done an analytical analysis, most of the wells in the desert pastures of Turkmenistan are of low yield, shallow. Thus, 85% of wells in the pastures of the North-Western part of Turkmenistan (Turkmenbashi region, Central Karakum, the right bank of the Amu Darya require less than 80 W of useful power for water lifting. For the wells of Zaunguz Karakum and especially the South-Eastern part of the country, a significant increase in the required power level up to 1 kW is typical and more. The lack of exact geographical coordinates for most wells makes it impossible for any other way to determine the power, except for the assignment of the data obtained to the entire territory of this area under consideration within its administrative boundaries [5, 7].

And 40% of all wells have a flow rate of less than 0.1 l/s, 30% - less than 0.2 l/s. It should be noted that due to the limited moisture reserves in the aquifer, even wells of modern engineering type have an insignificant flow rate. Wells with a depth of less than 40 m is 77.0%. However, there are deep and very deep wells (300 m and more). According to the flow rate and depth of the well, it is possible to determine the power required to lift water from the wells. The calculations are illustrated by histograms and tables for the vast majority of wells in Turkmenistan (60.8%). The useful power of SFVU for water lifting does not exceed 80 W, although in some cases the power reaches up to 6 kW.

The developed, created geoinformation map gives a general qualitative idea of the power values required for lifting water from wells, which is necessary when choosing and ordering water lifting and power equipment for mechanizing water lifting. Having information about the levels of required useful capacity obtained from the tables, choosing, taking into account the depth and flow rate of the well and the type of water-lifting mechanism, we draw up the distribution of the SFVU capacity for all available wells in the country. Thus, the data obtained are of direct interest for

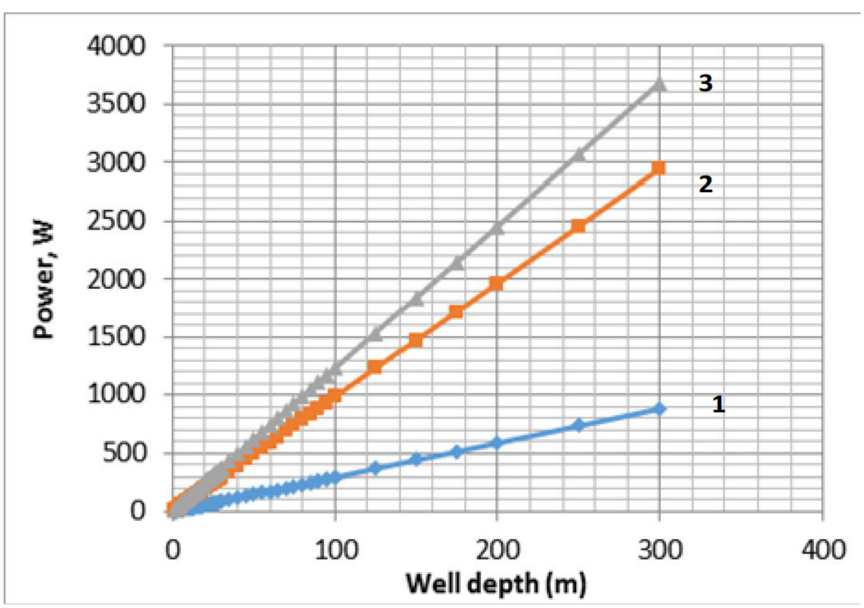

Figure 1: Dependence of the pump load power on the water pressure at various capacities: **1**-required lifting power; **2**- pump power input; **3**-power of solar water lifting installatio.

designers of autonomous solar photovoltaic water lifting installations and for the preparation of a feasibility study.

Since SFVU s do not operate around the clock, it is necessary to provide batteries as backup cells, which will be recharged from photocells during the daytime. It should be noted that HLFs do not pollute the environment, they have a rather long service life (at least 15-20 years) and high reliability, there are practically no operating costs and, importantly, highly qualified personnel and a repair base are not required for their maintenance.

The results of the analysis of the distribution of the total number of wells by the level of capacity for water lifting for each region of Turkmenistan are presented in the tables of my scientific works [7-14].

Compiled map of the pasture territory of Turkmenistan according to the required capacity for water lifting from wells, where it can be seen that the minimum capacity levels are typical for most of the country's territory.

The main type of service is seasonal azimuthal adjustment of photocells for more efficient operation and their periodic dust removal installations for 10 years.

Approximate calculations show that when more than 5,000 diesel mobile pumping stations are involved in circulation, at which 73 thousand tons of diesel fuel are burned annually, as a result of which approximately 233.5 thousand tons of CO_2 are emitted into the atmosphere per year. When using a solar photovoltaic plant, emissions will decrease by 5.6 times or by 82.2% [2-7, 10-14].

The developed installation can be used for water supply of garden and summer cottages, household plots and farms, distant pastures and other objects.

Calculation of capital costs. The cost of connecting to the nearest distribution network, as well as the quality and reliability of power supply, are important factors affecting the profitability of intensive pasture farms in the Karakum desert.

Under the current conditions, the use of SFVU is aimed at the following [3, 4, 7]:

- increasing reliability and reducing the cost of power supply in the structure of the cost of livestock products;
- minimization of production losses during interruptions in the network power supply, as well as to reduce the cost of electricity and fuel

Table 1: Estimated Cost of Installed HLF Equipment in the Karakum Desert in Dollar Terms

Name Quantity	Pieces Cost	Along USA	
		Units	Total
Basic option - diesel generator			
Diesel Generator FUBAGDS 3600 2.7, generator cost $32,870	1	547.8333	547.8333
Other materials	Kit	116.6667	166.6667
Cost of equipment Sob, USD	-		714.5
Installation and commissioning, man	-		142.9
Total capital investment K, USD	-		857.4
Basic variant - SFVU, 3 kW			
Solar module, 200 W	8	195.85	1566.8
Inverter "Axpert KS 3K 24V"	1	461.6667	461.6667
Battery SPG12-200 GE	3	364.5833	1093.75
60A Charge controller PC16-6015F60AMPPT	1	313	313
Other necessary materials - wire, protection devices, clips, connectors, fasteners, metal structures, building materials, etc.	Set	250	250
Equipment cost Sob, USD	-	3685.217	3685.217
Installation and commissioning, US dollars	-	500	500
Total. Capital investments K, USD	-	4185.217	4185.217
Additional capex in USD	-	900	900

used by standby gasoline and diesel generator sets.

Capital investments (K) are calculated by the formula:

$$K = K_{ob} + K_{sop,} \quad (1)$$

where K_{ob} - capital investments in working machines and equipment, including the costs of their acquisition, transportation and installation; K_{sop} - related investments.

To calculate the investment in the developed K_{ob} system, we will make an estimate for the installed automation equipment (Table **1**).

Capital investment in equipment in an enlarged form Kob

$$Kob = Sob\left(1 + \frac{Ktr}{100} + \frac{Km}{100}\right) \quad (2)$$

where Sob - selling price of equipment; Ktr - coefficient taking into account the costs of packaging and transportation, (8-10% of the selling price (contract value)); Km - coefficient taking into account the costs of equipment installation and commissioning; Kob, Km - the cost of equipment and its installation.

According to the above estimate, a diagram of the percentage distribution of capital costs for the equipment of an autonomous SFVU was constructed (Figure **2**).

***Definition of performance indicators*.** Like any other source of electricity, a photovoltaic installation is characterized by such parameters as costs (costs) for implementation and subsequent operation.

Current costs associated with the use of technical means:

$$Ie = ZP + Zob + A + R + E. \quad (3)$$

Depreciation costs can be expressed as follows:

$$A = \frac{H_a}{1} K, \quad (4)$$

where: Ha - annual rate of depreciation,%.

Maintenance and repair costs:

$$P = \frac{H_p}{100} K. \quad (5)$$

Where Hp is the annual rate of deductions for maintenance and repair, we accept 20%.

The cost of electricity generated by a liquid fuel generator:

$$C_d = \frac{K_g \cdot A \cdot t + C_{t} \cdot W_{s\,s} \cdot n_i \cdot t}{W_s \cdot n_i \cdot t} \quad (6)$$

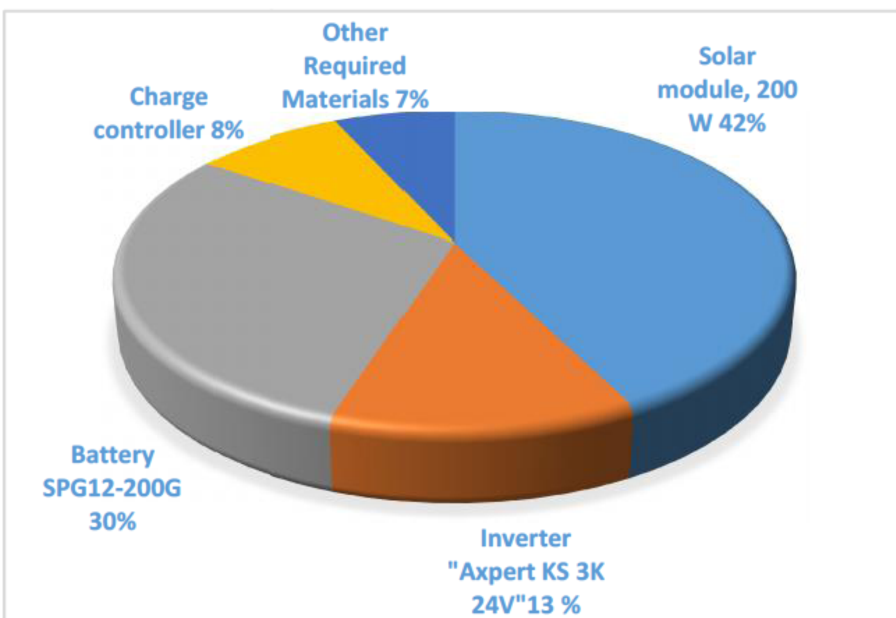

Figure 2: Percentage ratio of capital costs to the cost of HLF equipment.

Where K_g - investment in the generator set, US dollars; t - number of billing periods; n_i- number of days in billing periods; W_s - average daily electricity consumption, kWh; C_t - cost of fuel, US dollars.

Where ZP - the cost of paying maintenance personnel; Zob - general production and general business expenses (accepted in the amount of 10% of the ZP; A - depreciation deductions for the renovation of fixed assets; P - the cost of maintenance, current and major repairs; E - the cost of consumed energy resources (electricity, fuel).

The cost of generated energy from a photovoltaic installation:

$$C_S = \frac{Ie}{P * 8760 * t_p * N * k} \tag{7}$$

where: P - rated power, kW; N - is the service life of the installation, years; k - is the coefficient of the duration of work (when calculating, we take it equal to 0.6).

The average purchase price for diesel fuel is $500/t.

Estimated cost of fuel and lubricants -200 USD/year.

With a resource of 8000 hours at a load factor of more than 70%, the diesel power plant will have to be overhauled or replaced every 5 years.

The positive effect of the use of BI is expressed by reducing the level of voltage drop and the discharge current of the battery in an autonomous SFVU. Consequently, the load on the battery is reduced and the most favorable, "sparing" mode of operation is provided, the number of charge-discharge cycles increases, which affects performance.

2. DETERMINING THE EFFECTIVENESS OF INVESTMENTS FROM THE INTRODUCTION OF A PHOTOVOLTAIC INSTALLATION.

Let's calculate the indicators of investment efficiency. According to the magnitude of solar activity on the territory of the Krasnodar Territory, SFVU for 290 days a year works for 7 hours with maximum output. Based on this, we will approximately calculate the annual value of electricity generated by a station with a capacity of 2.5 kW.

$$W_y = P_m \cdot t \cdot n \tag{8}$$

where: P_max is the maximum power of the SFVU, kW; t is the time of effective operation during daylight hours, h; n is the number of days.

Payback period of investments:

$$t_0 = \frac{K + l_e}{W_y}. \tag{9}$$

Increasing profits by reducing operating costs:

$$\Delta Ch = I_1 - I_2, \tag{10}$$

whereare $I_1 - I_2$ the corresponding costs for the compared options.

Calculation of indicators of economic efficiency of investments is made on the basis of NPV and IRR.

Net present value NPV:

$$\text{NPV} = \sum_{t=0}^{n-1} \frac{CF_t}{(1+r)^t} \tag{11}$$

or

$$\text{NPV} = -K + \Delta\text{Ch}\frac{1-(1+r)^{-n}}{r}, \tag{12}$$

NPV $(r_1) < 0$, NPV $(r_2) > 0$.

where CF_t is income received in year t; r = 0.1 discount rate. Calculations are performed in prices as of August 2017. Discount rate E = 10%; settlement period T = 10 years. Internal rate of return (IRR):

Static payback period:

$$T_{0\,кс} = \frac{К}{\Delta С}. \tag{13}$$

Dynamic payback period

$$T_{0\,кд} = -\frac{\ln\left(1 - \frac{K}{\Delta Ch} r\right)}{\ln(1+r)}. \tag{14}$$

The results of the feasibility study carried out are summarized in Table **2**.

To assess the dynamics of movement (outflow and inflow) of funds, planning is carried out according to the Cash Flow methodology. Using the PVSOL7.0 program, we will simulate an autonomous SFVU with a nominal power of 3 kW. We accept the safety factor PR as 80% [7-9].

Table 2: Technical and Economic Indicators of the HLF in the Karakum Desert in US Dollars in Dollar Terms

Name Quantity	Pieces Cost	Along USA	
		Units	Total
Basic option - diesel generator			
Diesel Generator FUBAGDS 36002.7, generator cost USD	1	547.8333	547.8333
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As a result, obtaining the calculated values for capital and operating costs for an autonomous SFVU with a rated power of 2.5 kW for 20 years.

CONCLUSION

The issue of watering has not been sufficiently studied due to the lack of specific data on groundwater. Having studied the possibilities of energy and water supply of the desert zone and scientifically substantiated the eco-energy resources and potentials of solar energy in the desert zone of the Karakum. Came to the conclusion:

• to solve the country's food programs, it is necessary to develop transhumance pastoral animal husbandry in the desert zone of the Karakum;

• on the territory of the desert zone there are enough underground waters for development, reducing the cost of the desert product can be solved with the help of renewable energy sources of the sun and wind;

• the developed and created geoinformation map, the location of solar energy installations according to the power of the generated energy, depending on the depth of the wells in the pasture areas of Turkmenistan, will provide an opportunity for energy and water supply, the development of animal husbandry and the development of the desert zone of the Karakum;

• the given methodology for feasibility studies, capital investments, investment costs and evaluation of the effectiveness of operational parameters for use in transhumance will be useful in the preparation of a feasibility study (feasibility study);

• the capital investment for a 2.5 kW photovoltaic plant is US$4,185.2. Compared to the base case, operating costs for 1 year decreased by $1217.1. USA. The net present value of using a solar photovoltaic installation compared to a diesel-electric plant for a billing period of 10 years and a discount rate of 0.1 was 8694.72 US dollars. The cost of electricity generated from a photovoltaic installation amounted to 0.113 USD/kWh. The payback period for investments in a battery photovoltaic installation is 4.1 years, in a photovoltaic installation with a hybrid storage device - 4.6 years. As a result of the use of investors' batteries, a 30% reduction in operating costs is ensured by extending the battery life by 1.8 times.

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