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THE ASSESSMENT OF HYDROELECTRICITY DEVELOPMENT POSSIBILITIES IN SYUNIK REGION (ARMENIA)

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Հոդվածը ստացվել է՝ 15.09.24, ուղարկվել է գրախոսման՝ 20.11.24, երաշխավորվել է տպագրության՝ 13.12.24

Introduction. The effective use of small water sources in the RA Syunik region of the Republic of Armenia is of great importance from the point of view of saving fuel, and energy resources, and protecting the environment. This incentive will provide an opportunity to solve numerous regional problems caused by natural disasters, encroachments, and war situations.

Relevance. The development of hydroelectricity, especially in the Syunik region, is of vital importance for both Armenia and the region. The settlements of the region mainly use natural gas, hydropower, and some types of alternative energy, so from the energy security point of view, the use of small water flows to generate electricity is a relevant issue[1].

The aim of the article is to roadmap the use of small water bodies in the Syunik region by building hydroelectric power plants (mini-HPPs). The main practical implication of the study is the fact that the obtained results can be applied in the Syunik region.

Literature review. The economic development in the scope of sustainability and environmental protection is shaping the production practices of all the economic sectors. The ingredient of sustainability is added to every business project and the environmental aspect of economic activities has gained the same attention as the social and welfare aspects of the population. Studies show that the real sectors of the economy in RA have declining environmental efficiency[2], which further substantiates the need for new energy-efficient and sustainable business projects.

Water management is one of the directly linked spheres of the energy sector and environmental protection, since the use of hidropower in energy production is one of the main sources in electricity produciton in Armenia. Therefore efficient water management also assumes energy efficiency. The issue is apparent in both macro meso

1 Papikyan, S., New economic approaches to the development of hydroelectric power plants in Armenia. // Russia: development trends and prospects. Yearbook. Issue 17, part 2. Proceedings of the XIII International scientific and practical conference, Regions of Russia: development strategies and mechanisms for implementing priority national and regional projects and programs, Part 2. / M, 2022. 309-311.

2 Asatryan, H., Erkoyan, A., The Environmental Efficiency in RA Agrarian Sector: Dynamics and Prospects. The Contemporary Issues of Socioeconomic Development in the Republic of Armenia, 2024, 114–126. https://doi.org/10.54503/1829-4324.2024.1-114

and micro levels since water saving and water waste again are directly linked to energy efficiency[3]. Studies explore the two-sided essence of water management efficiency, where water use management is seen as the energy-saving aspect[4].

There are practically no energy/fuel resources in the RA, and water power plants are considered one of the primary sources of electricity for the RA[5]. The rivers in Armenia have special characteristics of mountain rivers: large declines and slopes, waterfalls and slides, flood-mud temporary rivers and beds, rainwater, snowmelt and underground feeding, and spring floods. It is particularly noteworthy that the flow mainly occurs in high-altitude zones[6] and from the point of view of water resources management, the construction of HPPs is important[7]. Several studies are dedicated to using the power potential of Armenian rivers [8].

Methodology. In the scope of the study, the main hydraulic equations and energy balance conditions for energy storage and conversion, design, and construction of hydroelectric power plants were used and implemented.

Analysis:The HPP is planned to be built in the Syunik region, on the left bank of the Vorotan River, near the Angeghakot reservoir. The head node of the HPP is planned to be built near the "Mets Aghbyur" spring located at 1810.0 m above sea level on the Vorotan River. It is a spring-connected structure with a water intake. The total length of the derivation is 400m, which currently exists and was previously made of steel pipes with a diameter of 0.40m. The capacity of the derivation is 0.102m^3/s.

HPP-standard parameters are:

- installed capacity: N = 63.0 kW;
- static pressure: Hs = 79.0 m;
- calculated pressure: H = 78.1m;
- calculated output: Q = 0.102 m^3/s.

The average annual amount of produced electricity is 550 thousand kWh.

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3 Wilson, L., Lichinga, K., Kilindu, A., Masse, A. Water utilities' improvement: The need for water and energy management techniques and skills. Water Cycle, 2, 2021, 32–37. https://doi.org/10.1016/j.watcyc.2021.05.002

4 Zimoch, I., Bartkiewicz, E., Machnik-Slomka, J., Klosok-Bazan, I., Rak, A., Rusek, S. (). Sustainable Water Supply Systems Management for Energy Efficiency: A Case Study. Energies, 14(16), 5101. 2021, https://doi.org/10.3390/en14165101

5 Source: www.minenergy.ampage/448, last accessed: 15/10/2024.

6 Concept of "Introduction of water-saving technologies", Appendix No. 1 of the RA Government's decision No. 39-L of January 17, 2019

7 Volnushkina, K., Bryanskaya, Yu., Hydraulic resistance of pipelines restored using polymer hoses. Hydraulic engineering. No. 9, 2023

8 Papikyan, S., Papikyan, M., The economic peculiarities of the construction of small hydroelectric plants. The Contemporary Issues of Socioeconomic Development in the Republic of Armenia, 2023, 45–55. https://doi.org/10.54503/1829-4324.2023.2-45

The Vorotan River has a mixed feeding system, where the maximum discharges are observed in April-July. The Vorotan River is the largest tributary of the Araks in the Syunik region. It originates from small lakes and springs on the northeastern slopes of the Syunik Plateau and the eastern slopes of the Zangezur mountain range. One of the largest tributaries of the Vorotan River is the Sisian River, which is its right tributary, flowing into it 107 km from the mouth, its length is 33 km, and the area of the catchment basin is 395 km^2. From the left bank, the river receives water from numerous springs of the Mukhurturyan, Angeghakot, Shaki, Zor-Zor, and Shinahayr. Thanks to those springs, the groundwater feeding of the river is quite significant (more than 50%), and the flow is constant in the low-water season.

The other geological conditions of the location are: average multi-year cumulative precipitation amount is 419 mm, the average annual wind speed is 1.5-2.5 m/s, and the maximum wind speed is 20 m/s. The vegetation is poor, it is mainly represented by mountain pastures and grasslands with little forest. The riverbed has severe bends along its entire length, in some places the bank is swamped due to the flow of groundwater and small tributaries. The riverbed is filled with gravel-pebble soil and rubble. The river valley has a V-shaped cut in the design section. The engineering-geological conditions in the location and the physical-mechanical characteristics of the underlying soils are favorable for HPP construction.

The electricity generated by the HPP is planned to be supplied to the general energy system of the RA.

The hydropower unit to be installed in the HPP building has an automatic regulation and control system. The plant equipment for control, automation, and monitoring ensures the normal operation of the HPP in automatic mode.
A separate area is planned for all the control panels of the hydropower plant inside the HPP building. The turbine valve is also located in the building.
Studies of the water regime of the "Mets Aghbur" spring show that the used values of the water flow resources necessary for the HPP are guaranteed and reliable.

Pressure losses in the pipeline were calculated according to the following formula:

$$h_w = 1.1 \cdot aAQ^2L,$$

Where:

A is the resistivity of the pipe;

Q is output; L is the length of the pipeline;

1.1 is a factor by which local losses are considered;

a is a correction factor / when the water speed is greater than 1.2 m/s, then a=1/.
The potential flow rate for the use of the HPP and the electricity production by month in the accounting year has been determined, and the results are presented in Table 1 (when Q=0.102 m^3/s).

Table 1[9]

The calculation of HPP parameters with three different pipe diameters

	Pipe diameter (meter)		
	0.3	0.4	0.5
Static pressure, m	79.0	79.0	79.0
Calculated pressure, m	75.2	78.1	78.7
Power, kW	61	63	64
Electricity output, million kWh	0.53	0.55	0.56
Capital investments, million AMD	40	42	44
Internal rate of profit, %	7.18	7.65	7.34
Investment payback period, year	12.2	11.6	12.0

The HPP is located in the territory of the Syunik region. The expediency of choosing the location of the HPP structures lies in the fact that the location allows for a short route to be taken for the derivation metal pipeline and effectively uses the hydropower resources of the existing source calculation site and the available opportunities on the site, resulting in an optimal arrangement of the water intake, derivation pipeline, HPP building, transformer substation, and high-voltage power transmission line. To carry out the work, there are transport roads, settlements, and power lines nearby. The HPP includes the following main structures: a water intake node, a pressure derivation pipeline, and The main HPP building.

The head node of the HPP is planned to be built near the "Mets Aghbyur" spring located at the 1810.0 m mark of the Vorotan River. It is a spring-connected structure with a water intake. It is planned to build a pressure derivation pipeline (pipe diameter 0.40 m, length 400 m). It starts from the water intake and ends at the turbine valve. The pipeline is mainly covered with natural soil.

The station node will be located on the left bank of the Vorotan River. The HPP building is of the above-ground type, where it is planned to install one hydropower unit with a total capacity of 63.0 kW. The dimensions of the HPP building are determined according to the dimensions of the unit and the arrangement of their auxiliary equipment. The cost effeciency forecasting of the HPP is presented in Table 2. Accodring to the table data the Total investments for the proposed HPP cost 41922979.3 AMD.

9 The table was composed by the author.

Table 2[10]

Cost efficiency forecasting (AMD)

Total output, kWh	552 670,5
Own needs (2%) and transportation loss (2%)	530 563,7
Gross income (kWh *tariff) thousand. AMD	11 174 201,9
Operating salary	
Operating costs, routine repairs, and breakdowns	2 883 140,2
Net income	8 291 061,6
Administrative salary	2 039 752,6
Administrative expenses	720 000,0
Fees and other mandatory fees	180 000,0
Amortization allocations (30 years, on full capital)	1 397 432,6
Water transportation costs	-
Other expenses	1 200 000,0
Profit before taxes	2 753 876,4
Profit tax	550 775,3
Net profit	2 203 101,1
Total investments	41 922 979,3

An electric bridge crane with a lifting capacity of 1.0 t will be installed in the HPP building. The foundations of hydropower unit are made of reinforced concrete. The walls of the machine building are made of stone masonry, and the roof is made of prefabricated reinforced concrete slabs.

The hydropower unit consists of a turbine: brand - A-100-H-80, power - 70 kW, 0.88, rpm - 600 rpm; generator, power - 100 kW, 0.92, rpm - 600 rpm, output voltage - 400 V. The water used by the HPP is discharged back into the river.

A temporary power supply for the construction is planned to be carried out from the nearest substation in the village of Angeghakot. Technical water supply is carried out at the expense of river water. A substation of 0.4/10 kV is planned near the HPP building, which is connected to the existing 10 kV power transmission line. The calculated output of the HPP is taken from the water intake being built on the "Mets Aghbyur" spring located at a height of 1810.0 m, from where the pressure pipeline begins and after the HPP building it is returned to the Vorotan River, without any change in quality and quantity. There is no need to cut down trees during construction since there are no trees and bushes in the area of the HPP structures. There is also no fauna here since it is located close to the road and settlements. The annual operating costs of electricity generation

10 The table was composed by the author.

consist of depreciation allowances (adopted linearly at the rate of 3.3% of the estimated cost), repair costs, staff salaries, administrative costs, and costs for the acquisition of materials (Table 3).

Table 3[11]

Energy performance indicators of the proposed HPP

1	Capacity (kWh)	63
2	Designed output (m3/s) Q	0,102
3	Static pressure (m)	79,0
4	Designed pressure h	78,1
5	Average multi-year electricity production (million kWh)	0,55
6	Amount of electricity sold, (million kWh)	0,53
7	Capital investments in the HPP (excluding VAT), thousand drams	41 923,0
8	thousand AMD / kW	419,23
9	AMD / kW Hour	79,02

The proposed measure holds not only high economic results but also environmental preservation value. In comparison with the construction of HPP and using the waterfall resources, the same amount of electricity would cause different types of pollution for the environment. The Table 4 provides the volumes of harmful substances emitted into the environment, when operating a thermal power plant with different fuels, to generate 0.55 million kWh of electrical energy.

Table 4[12]

The volumes of harmful substances emitted into the environment by a thermal power plant, tons

	Hard coal	Brown coal	Fuel oil	Natural gas
SO_2	2.7	3.5	3.4	0.001
Solid particles	0.64	1.22	0.32	-
NO_2	9.5	1.6	1.1	0.86
Fluorine compounds	0.02	0.05	0.001	-

Scientific novelty. The economic feasibility of building an HPP in the area of Vorotan River (at a height point of 1810.0 meters) was provided. The proposed measure

11 The table was composed by the author.

12 The calculations were made by the author according to the data retrieved from "U.S. Environmental Protection Agency (EPA). 2020 National Emissions Inventory Report. Detailed analysis of air pollutant emissions from various sources, including power plants. Last accessed November 11, 2024. Available at: EPA Air Emissions Inventories.

will provide 550 thousand kWh of energy annually and save 121 tons of organic fuel, thus solving numerous environmental issues.

Conclusions. The main research findings of the article are the following:

1. The economic feasibility of building a hydroelectric power plant (HPP) near the "Mets Aghbyur" spring (located at 1810.0 m above sea level of the Vorotan River) was provided. Calculations prove that 121 tons of organic fuel annually can be economized thus also solving environmental issues.
2. We can produce 550 thousand kWh of electricity annually can be produced thanks to the implementation of the proposed measure. The payback period of the proposed investments is 11.6 years.

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ՀԻԴՐՈԷՆԵՐԳԵՏԻԿԱՅԻ ԶԱՐԳԱՑՄԱՆ ՀՆԱՐԱՎՈՐՈՒԹՅՈՒՆՆԵՐԸ ՀՀ ՍՅՈՒՆԻՔԻ ՄԱՐԶՈՒՄ

ՊԱՊԻԿՅԱՆ ՍՏԵՓԱՆ
ՊԱՊԻԿՅԱՆ ՄԱՆՈՒԿ

Համառոտագիր

Վառելիքաէներգետիկ տեսուրսների խնայողության, շրջակա միջավայրի պահպանության, էներգետիկ անվտանգության տեսակետից կարևոր նշանակություն ունի ՀՀ-ի Սյունիքի մարզում փոքր ջրաղբյուրների արդյունավետ օգտագործումը: Այն հնարավորություն կտա լուծելու տարածաշրջանային բազմաթիվ խնդիրներ պայմանավորված տարերային աղետների, ոտնձգությունների, պատերազմական իրավիճակների հետ:

Հիդրոէներգետիկայի զարգացումը հատկապես ՀՀ Սյունիքի մարզում կենսական կարևոր նշանակություն ունի տարածաշրջանի համար:Մարզի բնակավայրերում հիմնականում օգտագործվում է բնական գազը,հիդրոէներգիան և այլընտրանքային էնէրգիայի որոշ տեսակներ:Էներգետիկ անվտանգության տեսակետից փոքր ջրահոսքերի օգտագործումը էլեկտրաէներգիա ստանալու համար **արդիական** խնդիր է համարվում:

Հոդվածի նպատակն է բացահայտել ՀՀ Սյունիքի մարզում փոքր ջրաղբյուների օգտագործման անհրաժեշտությունը հիդրոէլեկտրակայան կառուցելու միջոցով: Այն համեմատել ջերմային էլեկտրակայաններում արտադրված էլեկտրաէներգիայի հետ:

Հետազոտության ժամանակ օգտագործվել են հիդրավլիկայի հիմնական հավասարումները, ինչպես նաև ՀԷԿ-երի նախագծման և կառուցման հիմնական օրենքները:

Գիտական նորույթը: Հիմնավորվել է, որ Որոտան գետի 1810.0 մ նիշի մոտ գտնվող «Մեծ աղբյուր» աղբյուրի մոտ ՀԷԿ կառուցելու դեպքում տարեկան կարող է արտադրվել 550 հազար կՎտժ էլեկտրական էներգիա և տնտեսվել 121 տոննա օրգանական վառելիք՝ լուծելով բնապահպանական բազմաթիվ խնդիրներ:

Կիրառման հնարավորությունը: Ներկայացված գործնական առաջար-կությունը կարող է կիրառվել ՀՀ Սյունիքի մարզում՝ տնտեսապես և բնապահպանորեն հիմնավորված հիդրեէլեկտրակայանի կառուցման համար:

Բանալի բառեր: Հիդրոէլեկտրակայան, էլեկտրաէներգիա, գետ, հաշվային ճնշում, խողովակաշար, պատվար, հիդրոտուրբին, հզորություն, վառելիք, կապիտալ ներդրում, տոննա:

ЭКОНОМИЧЕСКИЕ ХАРАКТЕРИСТИКИ РАЗВИТИЯ ГИДРОЭНЕРГЕТИКИ В СЮНИКСКОЙ ОБЛАСТИ РА

ПАПИКЯН СТЕПАН
ПАПИКЯН МАНУК

Аннотация

Эффективное использование малых водных источников в Сюникской области РА важно с точки зрения экономии топливно-энергетических ресурсов, защиты окружающей среды, энергетической безопасности. Это даст возможность решить многие региональные проблемы, вызванные стихийными бедствиями, вторжениями и военными ситуациями.

Развитие гидроэнергетики, особенно в Сюникской области РА, имеет жизненно важное значение для региона. В населенных пунктах региона в основном используются природный газ, гидроэнергия и некоторые виды альтернативной энергетики. С точки зрения энергетической безопасности использование малых потоков воды для получения электроэнергии считается актуальной проблемой.

Цель статьи выявить необходимость использования малых водяных скважин в Сюникском марзе РА при строительстве гидроэлектростанции, сравнить ее с электроэнергией, производимой на теплоэлектростанциях.

В ходе исследований были использованы основные уравнения гидравлики, а также основные законы проектирования и строительства гидроэлектростанций.

Научная новизна. Обосновано, что если построить гидроэлектростанцию у источника «Мец агбюр» в районе отметки 1810,0 м реки Воротан, мы сможем производить 550 тыс. кВтч электроэнергии и экономить 121 тонну органического топлива, а также решить многие экологические проблемы. .

Применимость. Рекомендация может быть применена в разных регионах РА, особенно в Сюникской области.

Ключевые слова. ГЭС, электричество, река, давление, трубопровод, плотина, гидротурбина, мощность, топливо, капвложения, тонна.

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Abstract

The effective use of small water sources in the RA Syunik region of the Republic of Armenia is of great importance from the point of view of saving fuel, and energy resources, and protecting the environment. This incentive will provide an opportunity to solve numerous regional problems caused by natural disasters, encroachments, and war situations.

The development of hydroelectricity, especially in the Syunik region, is of vital importance for the region. The settlements of the region mainly use natural gas, hydropower, and some types of alternative energy, so from the energy security point of view, the use of small water flows to generate electricity **is a relevant issue**.

The aim of the article is to roadmap the use of small water bodies in the Syunik region by building hydroelectric power plants (mini-HPPs). The main practical implication of the study is the fact that the obtained results can be applied in the Syunik region.

In the scope of the study, the main hydraulic equations and energy balance conditions for energy storage and conversion, design, and construction of hydroelectric power plants were used and implemented.

Scientific novelty. The economic feasibility of building an HPP in the area of the Vorotan River (at a height point of 1810.0 meters) was provided. The proposed measure will provide 550 thousand kWh of energy annually and save 121 tons of organic fuel, thus solving numerous environmental issues.

The presented practical proposal can be applied in the Syunik region of the Republic of Armenia for the construction of an economically and environmentally sound hydroelectric power plant.

Keywords. Hydroelectric power plant, electricity, river, pressure, pipeline, dam, hydro turbine, capacity, fuel, capital investment, ton.