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Prospects for Small Hydropower in Ukraine in the Context of Feasibility and Environmental Impact: Summarising after the World Small Hydropower Development Report 2022

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Abstract **– The use of renewable energy and decentralization of energy generation in Ukraine has become a crucial and topical problem because of the war and devastating russian enemies' attacks on the Ukrainian critical energy infrastructure. Localized renewable energy generation stimulates humanitarian engineering that can support community peace-sustainability. However, before decision-making, appropriate resources and opportunities should be analyzed. An optimal way for a local energy generation portfolio development has to include a comprehensive feasibility analysis of projects accounting for key enablers and barriers and a full-fledged holistic environmental impact analysis of proposed technologies. At the same time, unworthy speculations touching people suffering have to be excluded, especially on the side of investors interested in the profits of the feed-in tariff. This article analyzes prospects for small hydropower in Ukraine in the context of its feasibility and environmental impact. The principal aim of the article is to answer the two questions. The first one is whether small-scale hydropower in Ukraine can principally pretend to play an essential role in localized renewable energy supply. The second one is whether the environmental impact of small hydropower in the country would be admissible in social and ecological contexts. The article is based on the World Small Hydropower Development Report 2022 materials, primarily regarding Ukraine.**

Keywords **– decentralization; environmental impact; feasibility; feed-in tariff; hydropower potential; renewable energy; small hydropower**

I. INTRODUCTION

Ukraine defines small hydropower (SHP) as hydropower plants (HPPs) with not more than 10 MW of installed capacity. In addition, HPPs with less than 200 kW of installed capacity are classified as micro- and those within the 200 kW and less than 1 MW range as mini-HPPs. Primarily this classification is explained by the assignment of the feed-in tariffs (FITs) value. The FIT is the largest for installations with a capacity of up to 200 kW and the smallest for small HPPs with a capacity of 1 MW or more, minimally ranging from 0.175 to 0.091 EUR/kWh exclusive of VAT on 31 Dec 2024 depending on commissioning date [1].

Although Ukraine has a relatively developed river network formed by more than 63,000 rivers and streams [2], the total feasible hydropower potential in the country, considering its area, is one of the lowest in Europe and the world [3]. It is estimated at 17-18 billion kWh in a year, while, for example, in Austria, whose area is almost 7.2 times smaller than the area of Ukraine – 53.7 billion kWh [4]. In length, more than 93 % of local watercourses are less than 10 km [2]. Many small rivers flowing through Ukrainian territory, where small HPPs are situated or planned, show a relatively low and uneven runoff, with up to 70 % or more of their annual runoff occurring during short periods of floods [2, 3]. In addition, most rivers have relatively small height differences from source to mouth. For rivers of the Dnieper basin covering nearly 65 % of the country's area it does not exceed 50–70 m, and in the Southern Bug basin (10.6 % of Ukraine's area) is about 100–150 m. In the Carpathians only (5%), rivers have a slightly greater height difference along streams, rarely exceeding 300-400 m [4]. Climate change is another concern for hydropower in Ukraine [5]. Among the main effects of climate change are: warmer winters and the frequent absence of a seasonal snow cover in much of the country [1, 2], whereas the hydrological regimes of the majority of Ukrainian's rivers depend on snow-melting. Heatwaves and long summer droughts are also becoming more common, so local rivers are experiencing declining runoff [2, 5].

The share of hydropower in the renewable energy mix of Ukraine in total decreased almost twice between 2010 and the first quarter of 2020, from 98.4 % to 44.9 %. SHP in 2020 accounted for less than 2 % of all hydropower production [3]. In turn, SHP plants yielded in the first quarter of 2020 less than 4.0 % of all electricity production of non-traditional renewable energy sources (excluding large hydropower), despite SHP belonging to the private sector and being eligible to benefit from the FIT. Primarily, this resulted from the development of other renewable energy technologies, mainly solar and wind power [1]. However, the main reason SHP does not play an essential role in Ukraine's renewable energy is the poor hydropower potential.

II. Small hydropower development in Ukraine: before and after feed-in tariff

A. Before the feed-in tariff

Small hydropower (SHP) should not be considered in terms of alternative renewable energy, because there has been more than a century of experience applying low-power hydraulic installations. The first HPPs were "small" by modern standards. For example, in the USA, although SHP has been considered an acceptable technology in most states' standard renewable energy portfolios (solar, wind, bio, hydropower), there are essential restrictions on new hydropower projects in such portfolios. This is explained by the technological maturity of hydropower, its stable financial standing, and environmental concerns [6].

The first HPP in modern Ukraine's territory was built in 1890 in Friedeshovo village (now Kolchyno, the Transcarpathian Region). The HPP had a capacity of about 200 kW. In central Ukraine, the first HPP with a capacity of 50 kW was built on the Southern Bug River in 1912 in the town of Tyvriv (the Vinnytsia region). Before the commissioning of the Dniprovska HPP (Dniproges) with a capacity of 640 MW in 1932, more than 150 HPPs were already operating in Ukraine, with a total capacity of about 8.4 MW [7]. Currently, they could have been defined as small HPPs. Mass construction of small HPPs in Ukraine started only after the Second World War. It was the period when the electrification of the country's agricultural areas was done with a combination of centralized and local energy supply. At the end of the 1960s, almost 1,000 small HPPs were operating in Ukraine. Most of them had a capacity of 5-25 kW. However, in the 1970s, with the development of large thermal, nuclear and hydropower plants in the USSR, the energy supply became more centralized and interest in small HPPs in Ukraine started to disappear. As a result, by the end of the 80s, only 49 small HPPs were operated in the country [7]. At the same time, contrary to Ukraine, in many countries, small hydropower has continued developing steadily since the commissioning of the first hydropower installations and until now [1, 3]. Admittedly, the main incentive for the stable development of small hydropower in the world was and remains the local factor [1, 3], when, along with available and significant hydropower potential capable of fully satisfying local needs, there is considerable complexity in the organization of centralized power supply. Then small HPPs become acceptable for local communities and profitable to produce in conditions of being local-constricted. For example, in Austria, only 2,882 HPPs out of more than 5,200 in 2015 were connected to the national grid. Others (mainly micro and mini HPPs with a capacity of up to 0.5 MW) worked for individual consumers or in local grids [8].

B. After the feed-in tariff

In 2009, the year of amendments to the Law of Ukraine "On Electric Power" [1, 7], which introduced the feed-in tariffs (FITs) for the state's purchase of electricity produced by alternative energy facilities, in particular, small HPPs, in the country there were only 46 small HPPs under operation with a total installed capacity of 49.2 MW. In 2010, there were 60 small HPPs (62.6 MW), in 2011 - 72 (70.8 MW), and in 2012 - 80 installations (73.5 MW) [9]. From this time, the number of reconstructed, modernized, and new small HPPs began to enlarge annually. In 2019, 157 small HPPs, with a total installed capacity of 114 MW, generated 242 GWh of electricity in Ukraine. In 2020, there were 167 small HPPs with a total installed capacity of more than 119 MW. In 2021, their number increased by 9 new installations and reached 176 [1, 3]. New small HPPs have been built as part of existing cascades that are already in operation (on the Southern Bug and its tributaries, as well as Sluch, Ros' and Seret Rivers) and on some free-flowing rivers (mainly on the rivers of the Ukrainian Carpathians). As for the social context, SHP in Ukraine is part of the country's Integrated Power System (IPS). None of the small HPPs in the country are stand-alone or related to independent schemes supplying electricity for local communities or any private needs [3], which is common world practice. At the same time, all small HPPs in the country belong to the private sector and have been developed eligible to benefit from the FIT [3]. The possibility of setting facilities on river sites favorable to private investors, first of all for easy connection to the IPS and eligibility to the FIT contributes to the fact that the number of small HPPs in the country continues to grow steadfastly [10]. Often small HPPs in Ukraine are developed spontaneously, without due regard for environmental issues. There have been numerous cases when small HPPs destroy untouched river ecosystems and harm local communities [3, 9]. There were many examples of non-compliance with existing building codes, violations of Ukraine's Water Code requirements, and the requirements of the Law of Ukraine on "Environmental Impact Assessment" (EIA) on the side of both SHP developers and regulatory agencies [3, 11].

III. Is small hydropower able to promote tackling energy problems in Ukraine?

Scientific articles and technical documents show several estimates of the total technical hydropower potential of SHP in Ukraine. They range from 280.0 MW to 1,140.0 MW installed capacity [1, 7]. The total feasible technical hydropower potential is estimated at up to 375 MW installed capacity [7]. The recent results of a market assessment of SHP rehabilitation in Ukraine by the World Bank indicated a total feasible technical potential for SHP development (including currently installed capacity) of approximately 280 MW [1, 12].

First of all, in assessing the unused hydropower potential of SHP in Ukraine, small and medium-sized rivers are mentioned, often mostly untouched rivers, for example, in the Carpathian region [7]. At the same time, Ukraine has a so-called "hidden" hydropower potential for SHP development. It can hide in existing non-powered dams, thousands of municipal and industrial reservoirs and ponds [2], and the widespread sewage and wastewater treatment infrastructure [3, 13, 14]. This hidden potential has not yet been thoroughly studied in the country although it could boost the implementation of successful SHP projects while reducing their potential adverse environmental impacts [3]. Two examples of SHP development in the country on wastewater treatment infrastructure (the Poltava small HPP, installed capacity of 190 kW, and the Kapustyanska small HPP, installed capacity of 484 kW) demonstrate

that small hydropower projects can be economically attractive and environmentally friendly [3].

However, the question of the real possibilities of SHP to tackle energy problems in Ukraine [4, 9, 15], in particular at the local level, taking into account energy decentralization purposes, remains relevant, and not only in the context of the completeness and correctness of the estimation of the available SHP's potential, including the involvement of "hidden" hydropower potential of the existing water infrastructure [1, 3].

Analysis of SHP development after feed-in tariff (FIT) implementation shows between 2013 and 2020, the installed capacity utilization rate (ICUR) of SHP in Ukraine decreased from approximately 44 % to 20 % (Table 1). At the beginning of 2020, the ICUR value with a 50 % exceedance probability was about 17 %, and its value with an 80 % exceedance probability was only about 9 % (Fig. 1). That is, 50% of the installed capacity of the domestic SHP had a 17% guarantee for use in need, and 80% provided only a 9% one. Firstly, it might be explained by the reduction of river runoff within the territory of Ukraine because of climate change and human activity on watersheds. Secondly, it might be explained by insufficient substantiation of new projects, for example, due to the overestimation of feasible hydropower potential [1, 3].

TABLE I. THE SMALL HYDROPOWER DEVELOPMENT DYNAMIC IN UKRAINE BETWEEN 2013 AND 2020

Year	Indicators		
	Installed capacity (MW)	*Electricity production (GWh)*	*ICUR[a] (%)*
2013	75	286	44
2014	80	251	36
2015	87	172	23
2016	90	189	24
2017	95	212	25
2018	99	231	27
2019	114	242	24
2020	119	209	20

a. ICUR – Installed capacity utilization rate

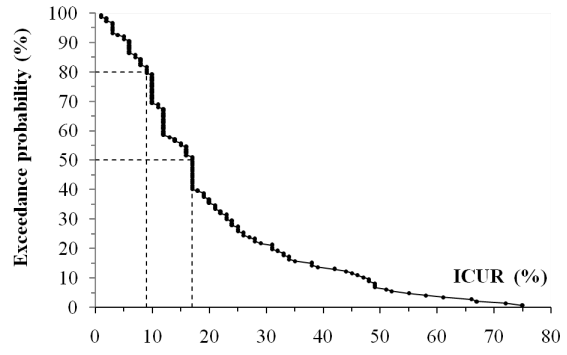

Figure 1. The ICUR values exceedance probability curve for 146 Ukrainian small HPPs as of the beginning of 2020

It should be noted that private owners of small HPPs in Ukraine have the right to freely supply the generated electricity to the IPS, unlike large HPPs that take part in regulation and are used as an emergency reserve. Due to the FIT, they are interested in producing more electricity and in the high ICUR values. So, small values of the ICUR may indicate insufficient reliability of domestic SHP as a stable energy producer in local power grids. For comparison, in 2019, the domestic wind energy industry reached the similar ICUR's value of 20% [1]. It should also be mentioned that many Ukrainian entrepreneurs focus on developing small HPPs with a capacity of up to 200 kW. Among installations put into operation in the last years, more than 80 % have a capacity not exceeding 200 kW and more than 43 % of all operating small HPPs in Ukraine have an installed capacity not exceeding 200 kW [10]. Thus, in the local dimension, for example within the modern rural community etc., such an installation can be considered only as a component of a diversified energy portfolio, as independently it can meet the needs of a quite limited range of consumers. There is a question will it be beneficial for the community to have a small HPP of its energy portfolio? There is also a question about the feasibility of using a small HPP as an emergency reserve, which can make it unprofitable even under feed-in tariff conditions.

Overall, the current regulatory framework of Ukraine provides good opportunities for the development of SHP in the country [1], sometimes even contrary to current legislation [11] and common sense in the context of feasibility [15]. It should be considered that small hydropower in Ukraine has now attained a poor reputation among numerous communities and environmentalists due to environmental issues caused by previous unsuccessful small HPP projects [1, 9, 11]. Therefore, environmental issues associated with SHP could be a high challenge in the future, if not properly addressed. For example, in 2017 the Chizhivs'ka small HPP near the city of Zviagel' appeared to be implicated in the extreme decline of water levels in the Sluch River, which required the temporary suspension of the plant's operation and a subsequent resumption of operation at reduced water discharges [11]. In particular, The World Wildlife Fund (WWF) in Ukraine [16] has repeatedly emphasized that the uncontrolled SHP development in the country can lead to the extinction of unique fish species and other aquatic organisms, deterioration of water quality, adverse changes in drainage and hydro-morphological regimes of rivers, etc. These impacts can also be exterritorial, spreading to other sections of the river and riparian areas downstream of the river, for tens and more kilometers, the consequences of which are practically impossible to minimize with traditional compensatory measures.

IV. THE SLUCH RIVER CASE

The Sluch River case can be mentioned as one of the indicative examples of both the poor performance and adverse environmental impact of SHP in Ukraine.

The Sluch River has a length of 451 km ranking as the 18th longest river in Ukraine. The river flows in Khmelnytsky, Zhytomyr and Rivne regions. The river catchment area is 13,800 km^2 and is found in the thirty in the country. The river drop is 181.0 m, the average slope of the water surface is 0.4 ‰. The Sluch River is the longest river of the fourth order in Ukraine, first flowing into the Horyn River before joining the Pripyat, which eventually feeds into the Dnieper [17].

Nine small HPPs are located on the Sluch River in Khmelnytskyi and Zhytomyr regions, with another small HPP (Novolabuns'ka) on its largest tributary, the Khomora River (Table 2). The total installed capacity of the Sluchans'ky cascade of ten small HPPs is 3,457 kW. The average installed capacity utilization rate is 14.2%.

TABLE II. HYDROPOWER IN THE SLUCH RIVER BASIN

Name of small hydropower plant	Indicators		
	Launch year/ restoration	*Capacity (kW)*	*ICUR[a] (%)*
Baranivs'ka	2017	382	10
Gubyns'ka	2014	200	16
Korzhivs'ka	1953/2004	320	10
Lubars'ka	1950/2006	200	11
Myropil's'ka	1958	500	8
Pedynkivs'ka	1959	600	11
Samchyky	2015	160	16
Chizhivs'ka	1951/2015	600	28
Chortoryis'ka	2013	363	10
Novolabuns'ka	2013	132	22

a. ICUR – Installed capacity utilization rate

Are there any questions about the feasibility of these SHPs compared to other technologies in reliability, affordability and efficiency, both the wide-country and local levels even without considering the serious harm made to the Sluch River ecosystem [11, 17]?

V. CONCLUSIONS

Private investors aim to promote SHP as an environmentally friendly alternative to other energy sources, including large hydropower. However, in the Ukrainian case, it is not quite clear if the impact of SHP on the environment is acceptable when comparing the adverse consequences with the energy possibilities.

At the same time, settling small hydro installations on existing infrastructure, especially critical ones, to provide an emergency reserve and contribute to energy saving may be feasible even without a FIT. Moreover, hardly similar small HPPs will provoke conflicts with local communities and hurt river ecosystems.

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