MANAGING THE ECONOMIC BENEFITS OF HYBRID RENEWABLE ENERGY SYSTEMS IN UKRAINE

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In an era of changes in the way of life of society with the rapid development of technologies and a decrease in dependence on fossil fuels for electricity production, the use of renewable energy sources (hereinafter – RES) for sustainable energy supply and without harming the environment is becoming increasingly important.

Electricity production technologies (hereinafter – EPT) based on alternative energy sources have inexhaustible properties for continuous use, however, each separately investigated source of electricity production has its own regional, technical and economic advantages and disadvantages for effective implementation, depending on the location region. Table 1 shows the results of calculating the indicators of economic efficiency of projects in the field of renewable energy on the example of wind power plants (hereinafter – WPP), solar power plants (hereinafter – SPP) and biomass power plants (hereinafter – BMPP) / biogas power plants (hereinafter – BGPP) in Ukraine.

Table 1

| №  | Indicators                                      | Units of measure | WPP  | SPP  | BMPP / BGPP |
|----|------------------------------------------------|------------------|------|------|--------------|
| 1  | “Feed-in tariff” for electricity under the law of Ukraine [1] | $cents/kWh       | 11.22| 17.93| 13.60        |
| 2  | Specific investment                             | $/kW             | 1500 | 1500 | 4300         |
| 3  | Installed capacity                              | MW               | 67   | 67   | 23           |
| 4  | Capacity factor                                 | %                | 0.40 | 0.12 | 0.75         |
| 5  | Annual operating cost rate                      | % of the investment amount | 1    | 1    | 3            |
| 6  | Income tax rate                                 | %                |      | 18   |              |
| 7  | Discount rate                                   | %                |      | 7    |              |

Table 1 (cont.)

| №  | Indicators                                      | Units of measure | WPP  | SPP  | BMPP / BGPP |
|----|------------------------------------------------|------------------|------|------|--------------|
| 8  | Percent                                        | %                |      | 7    |              |
| 9  | Loan repayment period                          | years            |      | 25   |              |
| 10 | Share of own investments                       | %                |      | 30   |              |
In any country in the world, the development of the energy sector is a factor that largely determines the vector of the country’s economic development, therefore, the creation of hybrid (combined) systems based on renewable energy sources can become an impetus for the development of the Ukrainian economy and sustainable energy supply to the population.

A hybrid renewable energy systems (hereinafter – HRES) is a combination of two or more renewable energy sources, which ensures sustainable production of electrical energy and a synergistic effect from hybridization (operation) of system elements [4]. In Ukraine, the HRES is gaining rapid development in theoretical studies that require further implementation in practice, while having a justified economic effect from implementation according to foreign experience.

Hybrid power supply systems can be used to supply power to consumers of three types, including:
- autonomous power supply, in which alternative energy sources are used in isolated power systems with energy storage systems (hereinafter – ESS);
- peak and backup power supply based on alternative sources in the area of the centralized network (with connection to the network and the sale of excess electricity at a “feed-in tariff” to the state);
- decentralized generation of energy in the area of the centralized network, in which HRES is used as the main source, while the transmission of electricity by the combined system is coordinated with the centralized network (to obtain additional energy from the network).

Foreign practice of HRES implementation indicates that combined systems have significant economic advantages in terms of return on monetary investments in comparison with individual elements of renewable energy sources. Table 2 shows the main economic indicators of studies of HRES projects in terms of system capacity, total system cost, electricity generation per year and return on investment (payback period) in different countries.

**Table 2**

| Country     | Elements of the HRES | Capacity (kW) | Total system cost ($) | Electricity generation per year (kWh) | Payback period (years) |
|-------------|----------------------|---------------|-----------------------|--------------------------------------|------------------------|
| India       | SPP+WPP+ESS          | 136.0         | 944 762.7             | 248 127.0                            | 4-6                    |
| Bangladesh  | SPP+BMPP+ESS         | 13.8          | 26 072.5              | 3 724.6                              | 8-10                   |
Various EPT have their own economic performance indicators, which are systematized in Table 3. The largest costs for the installation of capacities are required for traditional energy sources (nuclear and thermal power plants) – 6.1-6.9 thousand $/kW, while the lowest costs are required for RES: WPP (1.5-1.9 thousand $/kW) and SPP (1.4-4.4 thousand $/kW).

Table 3

| Country | Elements of the HRES | Capacity (kW) | Total system cost ($) | Electricity generation per year (kWh) | Payback period (years) |
|---------|----------------------|---------------|-----------------------|-------------------------------------|-----------------------|
| Portugal | SPP+WPP+SHPP*+ESS   | 9 540.0       | 3 781 742.0           | 599 189.8                          | 8-10                  |
| Bangladesh | SPP+BMPP+ESS       | 176.0         | 1 383 410.0           | 492 428.0                          | 11-13                 |
| Jordan   | SPP+WPP+ESS         | 44 000.0      | 44 171 644.0          | 145 642 882.0                      | 4-6                   |

*SHPP – small hydroelectric power plants
Source: compiled by the authors based on [5;6;7;8;9]

Hybrid systems acquire a number of attractive properties that make it possible to consider them as the basis for a new stage in the development of energy, due to such features as:
- increasing the energy independence of consumers;
- smoothing of peak loads;
- decrease in the level of required capacity redundancy;
- minimization of losses during transmission (transportation through the network) of electricity;
- possibility of using local energy resources.

When choosing a technology for establishing HRES, climatic features are an important criterion for installing the system. Depending on the climatic characteristics, it is necessary to consider various combinations of RES and calculate feasibility studies. In conducting a feasibility study, optimization methods should be considered to determine the efficiency, economy and reliability of the HRES operation.

Due to the development of technological progress, which contributes to the emergence of new opportunities and innovations in this area, the demand for hybrid energy systems is increasing significantly. Regions, cities and villages are particularly interested in these solutions, as they represent a means of effectively managing supply and demand, thereby increasing energy security and energy independence.

It is important to introduce hybrid systems to provide uninterrupted electricity to special facilities (medical, military and food establishments, etc.), which will have
several degrees of sustainable “energy protection”, for example, when the HRES operates in a combination of WPP+SPP+ESS, the power system will have a three degree of “energy protection”: the operation of three elements, the operation of one of the RES elements, the operation of ESS before the start of operation of one or several RES elements in the system.

On the territory of Ukraine, the wind speed is low in summer, when, for example, the sun shines brightly and for a longer time than in winter (there are about 260 sunny days or 3 060 hours in one year, and the total potential wind potential during the operation of a wind farm is 8 760 hours) [3]. In winter, when there is less sunshine, the wind blows stronger. Since the peak operating time, for example, for WPP and SPP occurs at different times of the day and year, with the help of HRES, the likelihood of having a constant power supply will be higher compared to individual RES.

Foreign experience of using HRES indicates that the majority of hybrid installations are autonomous combined systems that operate “off the grid” (not connected to the electricity distribution system). At the same time, when, for example, neither wind nor solar systems produce energy, most combined systems provide access to electricity through ESS. The addition of CHE makes the systems more complex, but modern electronic controllers can control these systems automatically.

Conclusions. The rapid and positive dynamics of the development of economic indicators of the efficiency of alternative energy sources is the result of a consistent state policy aimed at developing the use of renewable energy sources, which ensures an increase in environmental and energy security, as well as diversification of energy sources.

Due to various combinations of hybrid energy systems, it is possible to obtain a synergistic effect from the use of various RES-based facilities with the following advantages:

- Efficiency. High-tech interconnections of different energy sources based on renewable energy sources can guarantee high efficiency of energy production, thanks to the storage of excess electricity in the ESS, as well as intelligent management of energy consumption with low losses.
- Innovativeness. The main purpose of the power supply of the hybrid system is to achieve a balance between production and consumption. This requires the integration of various technologies for the production and storage of energy, which contribute to new innovative solutions based on RES.
- Network independence. HRES are composed of at least two different energy sources that create a synergistic effect of use. Combinations of various EPT based on RES are possible to create innovative and energy-efficient solutions for cities, districts or villages (without connection/dependence on the network of a region, district).
- Sustainability. By combining renewable energy sources such as solar, wind, hydro or bio power plants, hybrid systems can provide 100% green (clean) energy with the added benefit of flexibility in use and the ability to adapt to electricity demand (flexible capacity in the system).

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