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DOI: <https://doi.org/10.30525/978-9934-26-398-9-4>

CURRENT STATE OF RENEWABLE ENERGY SOURCES USE. EFFICIENCY ANALYSIS BASED ON SYSTEM DYNAMICS CONCEPT

1. The need for widespread use of renewable energy sources (RES) – wind, solar, bio, hydro, geothermal, etc. – is determined by the rapid growth in the need for electricity, which is expected to double by 2030 and quadruple by 2050 compared to 2000 [8]; by the depletion of organic fuel reserves in the foreseeable future and the current problems of their supply; the crisis state of the environment due to pollution with nitrogen and sulphur oxides, carbon dioxide, etc.

Many EU countries have announced plans to develop RES, particularly wind and solar plants (see, for example, [7]). The US and the EU have announced ambitious goals for the development of offshore wind power by 2030 – 30 GW in the US and at least 60 GW in the EU. The new EU target is to reach 60 GW by 2030 and 300 GW by 2050 [12].

2. The contribution of alternative energy to the total production of electricity in the world is almost 23%, while the lion's share falls on hydropower – 16.6% [8]. According to [10], 40% of all countries have clean power as the largest source of their total electricity generation. Among the European countries, the top ten leaders in the use of clean energy include Norway (6th place, 98.3%), Switzerland (7th place, 97.4%), Iceland (8th place, 96.2%) and Albania (10th place, 94.8%). Ukraine (5%) ranks in the bottom five for this indicator, though in terms of the rate of development of renewable energy in 2019, it was among the TOP-10 countries in the world and, in 2020 – among the top-5 European countries in terms of the rate of development of solar energy [15].

3. The top 5 countries that annually invest the most in RES include China (from 2016 to 2020 – an average of 68.6 billion euros), the United States (about 35 billion euros), Japan (from 8 to 12 billion euros), India (since 2010 year – from 5.11 to 11.9 billion euros) and Germany (8.9 billion euros) [15].

4. Ukraine has favourable natural conditions for developing wind, solar and bioenergy. According to Ukraine's updated energy strategy until 2035 [13], the share of alternative energy should be 30% of the total volume of energy produced by Ukraine, corresponding to Ukraine's obligations to the European Energy Community.

5. According to [14], at the end of 2021, the capacity of Ukraine's renewable energy sector (primarily solar and wind plants) reached 9655.9 MW, including solar installations for private households. Although RES are often economically more expensive than traditional energy sources and fuels today, it is assumed that along with the future development of technologies, the cost of energy based on RES will decrease, and their production will become more and more profitable [9].

6. The war has significantly affected the volume of electricity production by RES facilities. According to experts' estimates, as of August 2022, 30–40% of RES power plants in Ukraine's southern and southeastern regions were damaged in one way or another. Besides, in 2022, 800 MW of new wind energy capacities were to be implemented in Ukraine, but the construction of wind farms was suspended [14].

7. Assessments of the effectiveness of RES use are influenced by such factors as the size of the country's total energy market, total costs per unit of power/unit of RES generation, electric power consumption per capita, CO₂ emissions & air pollution, RES electricity generation, % of RES as of total energy production etc. [11].

8. Analysis of the possibilities of applying modelling, in particular the system dynamics methodology for displaying cause-and-effect relationships between factors/variables that determine the patterns of development of the RES market and for quantitative assessment of RES effectiveness showed that this simulation concept has long been successfully used for forecasting the development of the economy and energy as a whole (on the scale of the world, continents and separate countries), as well as taking into account environmental factors and evaluating the efficiency of investments in RES – starting from classic T. Fiddaman's model [3] up to current ones [1; 2; 4–6] etc. Over the past five years alone, more than 30 publications devoted to the development of clean energy have been published in the conference proceedings of the System Dynamics Society.

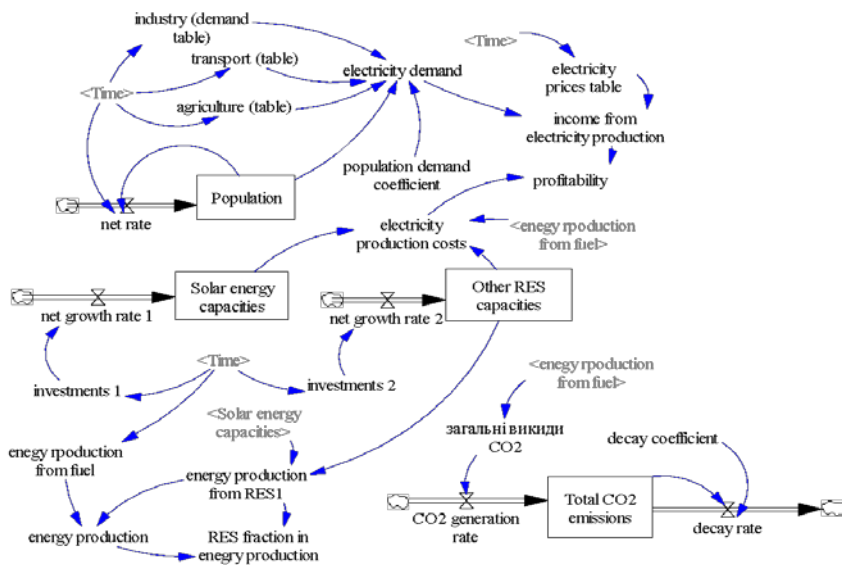


Figure 1. Base structural model

9. The analysis of reference system-dynamic models made it possible to formulate key assumptions and build a basic structural model reflecting the dynamics of economic and environmental indicators caused by the demand for electricity and the development of renewable energy sources is presented in Fig. 1. It is assumed that the growth of RES capacities is carried out at the expense of state and foreign investments. CO₂ emissions are considered to be the main environmental indicator.

The direction of the further work is to deepen and expand the assumptions of the basic model to build a full-fledged system dynamic model that could be used to forecast and evaluate strategies and the effectiveness of the implementation of alternative energy policy in Ukraine, taking into account total electricity demand, costs and prices.

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