ABSTRACT

The doctoral dissertation is a comprehensive and innovative analysis of the energy use of hydrogen produced from excess electricity from renewable energy sources (RES) for the production of alternative fuels such as synthetic natural gas (SNG) and ammonia. The work combines an extensive literature review, process modeling, technological and economic analyses, making it a significant contribution to the development of Power-to-Fuel technology.

The aim of the work was to create a comprehensive model covering the entire technological chain - from energy generation from a wind and photovoltaic farm (each with a capacity of 5 MW), through hydrogen production by electrolysis, to the synthesis of SNG and ammonia. The detailed analysis of the operation of RES farms included the annual cycle of energy production, taking into account variable weather conditions, downtimes and operating hours. Day and night valleys were analyzed, in which excess energy was directed to the hydrogen generator, which allowed for precise determination of the amount of available energy and electrolysis efficiency.

Aspen Plus was used for process modeling, analyzing the impact of key parameters such as temperature and pressure on the system performance and efficiency. Optimal conditions (2 MPa and 100°C for SNG and 20 MPa and 300°C for ammonia) allowed to achieve yields of 1.98 kg CH_4/kg H_2 and 5.54 kg NH_3/kg H_2.

The work is distinguished by the use of ORC modules and Stirling engines for waste heat recovery, which increased the efficiency of the installation to 0,8617 for SNG and to 0,9848 for ammonia. Economic analysis, based on data for 2022 and 2025, showed that the key factors influencing production costs are energy and hydrogen prices - an increase in energy prices by 60% caused the increase of SNG costs to $7.56/kg and ammonia to $2.82/kg.

The dissertation contains a detailed analysis of the impact of process parameters on the efficiency of systems, identifies key technological challenges and proposes their solutions, which makes it a valuable source of knowledge for future research and implementation. The originality of the work is demonstrated by a holistic approach to the analysis of the entire technological chain and a detailed assessment of the operation of RES, electrolysis and fuel production, which is a significant contribution to the development of hydrogen technologies and decarbonization of energy systems.