Zahra Moshaver Shoja, Ali Bohluli Oskouei, Morteza Nazari-Heris, 2025, Risk-based optimal management of a multi-energy community integrated with P2X-based vector-bridging systems considering natural gas/hydrogen refueling and electric vehicle charging stations, *Renewable Energy Focus*, 53 (2025) 100680.

Abstract Growing environmental concerns have increased interest in renewable energy-powered natural gas/hydrogen refueling (NGHR) and electric charging (EC) stations, driving the adoption of advanced energy resources like power-to-X (P2X) technologies in energy systems. This paper introduces vector-bridging systems (VBSs). In this concept, P2X technologies coupled with energy storage form a bridge across multiple energy vectors, such as electricity, gas, heat, and hydrogen, to enhance flexibility in community-integrated energy systems (CIESs). We propose a risk-based optimal energy management framework that integrates P2X-based VBSs to optimize participation in multi-energy markets while meeting power, gas, heat, and hydrogen demands from NGHR and EC stations at minimum cost. An incentive-based integrated demand response (IDR) model is also incorporated to reduce daily operation costs for power and heat demands. To manage uncertainties, a hybrid multi-objective info-gap decision theory (MOIGDT)/stochastic programming approach is used, adapting to the nature and knowledge of uncertain parameters. The multi-objective problem is solved using the augmented ε-constraint method, with the best solution selected through fuzzy decision-making and the min-max approach. Numerical results demonstrate that the combined use of P2X-based VBSs and IDR lowers daily operating costs by up to 8.36% and reduces risk levels in short-term CIES scheduling by 11.3%, underscoring the effectiveness of VBSs in achieving cost-efficient, resilient energy management.

Keywords Multi-energy communities, vector-bridging systems, hybrid refueling stations, power-to-x technologies, integrated demand response, risk-averse hybrid approaches.

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