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# DESIGN AND OPTIMIZATION OF OFF-GRID HYBRID ENERGY SYSTEM FOR SMALL ISLANDS

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**Abstract** – Small islands are at the forefront of just energy transition. While their closed environment supports low energy footprint, there are several challenges related to achieving a high renewable fraction without resorting to component oversizing or energy curtailment. This study aims to design and simulate a hybrid energy system for meeting energy demands of a small island in Estonia. At first, an off-grid renewable microgrid concept is conceived as the case study for Vormsi island. The electrical and thermal load for the proposed microgrid is obtained from publicly available databases. Photovoltaic (PV) and wind power systems were taken as the source for the electrical demand. The thermal load is represented through a thermal load controller that converts surplus renewable electricity into useful heat. A natural gas boiler and battery storage are integrated into microgrid to mitigate the intermittency of renewable electricity. Secondly, HOMER Pro software is used to identify the optimal system design by minimizing the net present cost while meeting reliability constraints such as zero annual capacity shortage and operating reserve requirements. It also evaluates the feasibility of the sizing combinations that involve trade-offs between generation, storage, and conversion capacities. It was observed that a PV-dominant microgrid solution can deliver the required energy loads. Battery storage on the order of tens of megawatt-hours provided multi-hour energy autonomy, keeping the renewable fraction close to 98 percent. The annual operating cost for the optimal configuration is estimated to be approximately USD 660 000. The results showed that integrating wind generation can mitigate PV oversizing and improve cost benefits compared to PV-only configurations. The simultaneous operation of electric-thermal loads increased renewable energy utilization, effectively minimizing fuel consumption of backup boilers. This study provide insights for policymakers and island municipalities that are pursuing reliable, clean, and affordable energy solutions, especially in the Baltic Sea Region.

**Keywords** – HOMER Pro; hybrid systems; off-grid microgrid; small islands; techno-economic analysis

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