ABSTRAK

Transisi menuju sistem energi rendah karbon merupakan tantangan besar bagi sistem kelistrikan terisolasi di Indonesia, termasuk Baubau-Raha yang 75,69% energinya masih bersumber dari pembangkit fosil. Pada tahun 2023, *reserve margin* sistem ini hanya 19,52%, jauh di bawah batas aman. Untuk meningkatkan keandalan dan mendukung dekarbonisasi, *Generation Expansion Planning* (GEP) menjadi penting. Umumnya GEP bertujuan meminimalkan biaya produksi listrik, namun dalam pencapaian target nasional bauran EBT dan penurunan emisi karbon, GEP perlu menginternalisasikan dampak lingkungan akibat emisi karbon ke dalam model optimasi. Selain itu, agar hasil perencanaan lebih optimal dan realistis, ketidakpastian biaya investasi dan variabilitas produksi pada pembangkit EBT variabel seperti PLTS dan PLTB juga harus diperhitungkan.

Penelitian ini menggunakan perangkat lunak *Low Emission Analysis Platform* (LEAP) yang terintegrasi dengan *framework Next Energy Modeling Optimization* (NEMO) berbasis *Linear Programming* (LP) untuk mengoptimalkan GEP di sistem Baubau-Raha pada periode 2024–2050. Internalisasi eksternalitas dilakukan melalui penerapan *carbon tax* sebagai representasi harga karbon nasional. Empat skenario perencanaan diuji, yaitu *Business as Usual* (BaU), EBT Lokal, EBT Lokal dengan *Storage*, dan EBT Lokal dengan Interkoneksi ke sistem Sulbagsel. Hasil penelitian menunjukkan bahwa seluruh skenario mampu menjaga margin cadangan sistem di atas 35%. Namun, dari sisi ekonomi dan lingkungan, skenario EBT Lokal dengan Interkoneksi memberikan kinerja terbaik dengan *Levelized Cost of Electricity* (LCOE) sebesar Rp2.040,33/kWh (dengan eksternalitas) dan potensi penurunan emisi karbon sebesar 54% dibanding BaU pada tahun 2050. Skenario ini juga mampu mencapai bauran EBT lebih dari yang ditargetkan dalam Rencana Kebijakan Energi Nasional (RPP KEN). Dengan demikian, dalam kasus ini integrasi EBT variabel yang dikombinasikan dengan interkoneksi regional terbukti menjadi strategi ekspansi paling optimal, memberikan *trade-off* terbaik antara biaya, penurunan emisi, dan keamanan pasokan energi.

Kata Kunci- *generation expansion planning*, energi baru terbarukan, biaya eksternalitas *carbon tax*, LEAP-NEMO, *levelized cost of electricity*

ABSTRACT

The transition towards a low-carbon energy system presents a major challenge for isolated power systems in Indonesia, including the Baubau-Raha grid, where 75.69% of electricity supply still relies on fossil fuel-based generation. In 2023, the system's reserve margin stood at only 19.52%, significantly below the national minimum threshold, thus posing an elevated risk to supply reliability. To enhance system reliability while supporting decarbonization efforts, Generation Expansion Planning (GEP) plays a vital role. Conventionally, GEP focuses on minimizing electricity costs; however, in the pursuit of national targets for renewable energy penetration and emission reduction, GEP must also internalize environmental impacts from carbon emissions into the optimization framework. Furthermore, to achieve optimal and realistic planning outcomes, uncertainties related to investment costs and production variability from variable renewable energy sources, must be considered.

This study employs the Low Emissions Analysis Platform integrated with the Next Energy Modeling Optimization framework based on Linear Programming to optimize the GEP for the Baubau-Raha system over the period 2024–2050. The internalization of externalities was conducted through the application of a carbon tax to represent the national carbon price. Four planning scenarios were evaluated: Business as Usual (BaU), Local Renewables, Local Renewables with Storage, and Local Renewables with Interconnection to the Sulbagsel grid. The results show that all scenarios maintain system reserve margins above 35%. However, in terms of both economic and environmental performance, the Local Renewables with Interconnection scenario demonstrates the most optimal outcome, achieving a Levelized Cost of Electricity (LCOE) of Rp2,040.33/kWh with externalities and a potential 54% reduction in carbon emissions compared to BaU by 2050. This scenario surpasses the national renewable energy share targets set by the National Energy Policy, highlighting that in this case an integrated approach combining renewables with interconnection offers the best trade-off between cost, emissions reduction, and energy security.

Keywords- generation expansion planning, renewable energy, carbon tax externality costs, LEAP-NEMO, levelized cost of electricity.