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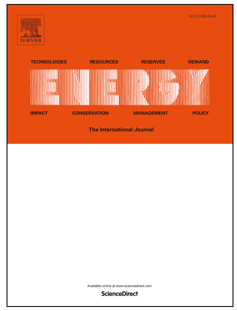

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Optimal design and operations of a flexible oxyfuel natural gas plant

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Abstract

We co-optimize the design and operations of a flexible semi-closed oxygen-combustion combined cycle (SCOC-CC) carbon capture plant under time-varying electricity prices. The system consists of a cryogenic air separation unit, liquid oxygen storage, a gas turbine, a heat-recovery steam generator, and a steam turbine. The gas turbine is modeled allowing part-load operation. Computational optimization is used to maximize net present value (NPV) in order to examine the potential benefits achievable through upfront investments in increased flexibility (i.e., allowing price arbitrage between times of low and high price). Case studies of Germany and California are examined. Flexible SCOC-CC systems are not profitable in either region under current electricity prices. With electricity prices ≈2 times current prices, we find systems with positive NPVs. Oxygen storage is used in days with extreme price variability. Optimal designs favor constant operation, without over- or under-sizing system components and without additional oxygen storage. Sensitivity analyses show that external factors such as mean electricity price (± 200%), natural gas price (± 150%), and nominal discount rate (± 50%) have the strongest effect on NPV. Electricity price variability, which is thought to increase with increased penetration of renewables, does not strongly impact system design and profitability.

Keywords: Nonlinear Optimization, Semi-closed oxygen-combustion combined cycle, Thermodynamic and cost modeling, Carbon capture, Gas turbine, Air separation unit

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