

Operability and Operating Cost Analysis of a Hydrogen Supply Chain Integrated with Renewable Energy Sources

Mayra Thomás Oliveira^a, Thiago Vaz da Costa^a, Luís Cláudio Oliveira-Lopes^a, Fernando Vines Lima^b,
Sérgio Mauro da Silva Neiro^{a*}

^a Faculdade de Engenharia Química (FEQ), Universidade Federal de Uberlândia (UFU), Uberlândia-MG, Brazil

^b Department of Chemical and Biomedical Engineering, West Virginia University, Morgantown, WV, United States

*srgneiro@ufu.br

ABSTRACT

Hydrogen Supply Chains (HSCs) have progressively evolved from cost-driven optimization approaches toward frameworks that incorporate uncertainty, multi-period planning, and decarbonization objectives. However, researchers have not sufficiently explored the simultaneous evaluation of process operability and operating costs in integrated hydrogen supply networks, particularly for hybrid systems combining conventional and renewable-based production routes. In this context, this work rigorously analyzes operability and operating costs in a hydrogen supply chain using an integrated process simulation framework. The proposed hydrogen supply chain (HSC) model was developed in AVEVA Process Simulation (APS), a process modeling software. It consists of two geographically distributed production hubs. These are connected to five consumers via a pipeline network. The first hub includes three units: steam methane reforming (SMR, a hydrogen production process using natural gas), water electrolysis (splitting water into hydrogen and oxygen using renewable electricity), and hydrogen liquefaction. The second hub comprises SMR and liquefaction facilities. The operability assessment was performed by integrating APS with Opyrability, an open-source Python-based operability analysis tool. Opyrability was developed by the Control, Optimization, and Design for Energy and Sustainability (CODES) group at West Virginia University. This framework enables the evaluation of feasible operating regions. It also clarifies the relationship among hydrogen production allocation, supply chain operability, and operating cost. Results show that isolated cost-based analyses can yield unfeasible production targets. In contrast, integrated operability-cost assessments provide more realistic operating policies and improve allocation among production hubs. Including renewable-based electrolysis increases operational flexibility and expands the feasible operating region. Overall, the proposed methodology provides a valuable decision-support tool for the design, planning, and operation of low-carbon hydrogen supply chains.

Keywords: hydrogen supply chain, green hydrogen, process simulation, operability, operating cost

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