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An Analysis of Economical Drivers and Technical Challenges for Large-Scale Biohydrogen Deployment

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Abstract : This study includes learnings from an engineering practice normally performed on large scale biohydrogen processes. If properly scale-up is done, biohydrogen can be a reliable pathway for biowaste valorization. Most of the studies on biohydrogen process development have used model feedstock to investigate process key performance indicators (KPIs). This study does not intend to compare different technologies with model feedstock. However, it reports economic drivers and technical challenges which help in developing a road map for expanding biohydrogen economy deployment in Canada. BBA is a consulting firm responsible for the design of hydrogen production projects. Through executing these projects, activity has been performed to identify, register and mitigate technical drawbacks of large-scale hydrogen production. Those learnings, in this study, have been applied to the biohydrogen process. Through data collected by a comprehensive literature review, a base case has been considered as a reference, and several case studies have been performed. Critical parameters of the process were identified and through common engineering practice (process design, simulation, cost estimate, and life cycle assessment) impact of these parameters on the commercialization risk matrix and class 5 cost estimations were reported. The process considered in this study is food waste and woody biomass dark fermentation. To propose a reliable road map to develop a sustainable biohydrogen production process impact of critical parameters was studied on the end-to-end process. These parameters were 1) feedstock composition, 2) feedstock pre-treatment, 3) unit operation selection, and 4) multi-product concept. A couple of emerging technologies also were assessed such as photo-fermentation, integrated dark fermentation, and using ultrasound and microwave to break-down feedstock`s complex matrix and increase overall hydrogen yield. To properly report the impact of each parameter KPIs were identified as 1) Hydrogen yield, 2) energy consumption, 3) secondary waste generated, 4) CO2 footprint, 5) Product profile, 6) $/kg-H2 and 5) environmental impact. The feedstock is the main parameter defining the economic viability of biohydrogen production. Through parametric studies, it was found that biohydrogen production favors feedstock with higher carbohydrates. The feedstock composition was varied, by increasing one critical element (such as carbohydrate) and monitoring KPIs evolution. Different cases were studied with diverse feedstock, such as energy crops, wastewater slug, and lignocellulosic waste. The base case process was applied to have reference KPIs values and modifications such as pretreatment and feedstock mix-and-match were implemented to investigate KPIs changes. The complexity of the feedstock is the main bottleneck in the successful commercial deployment of the biohydrogen process as a reliable pathway for waste valorization. Hydrogen yield, reaction kinetics, and performance of key unit operations highly impacted as feedstock composition fluctuates during the lifetime of the process or from one case to another. In this case, concept of multi-product becomes more reliable. In this concept, the process is not designed to produce only one target product such as biohydrogen but will have two or multiple products (biohydrogen and biomethane or biochemicals). This new approach is being investigated by the BBA team and the results will be shared in another scientific contribution.

Keywords : biohydrogen, process scale-up, economic evaluation, commercialization uncertainties, hydrogen economy
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