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An Optimization-Based Design and Analysis of B2H2 (Biomass-To-Hydrogen) System

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Extended Abstract

Biomass is a promising alternative to meet future energy demand as an only renewable source of carbon-based fuels. Hydrogen, one of the most promising next energy carrier, can be produced by various primary resources from non-renewable energy sources (e.g., oil, coal, and natural gas) to renewable energy sources (e.g., wind, solar, and biomass). In this study, we develop a new optimization model using mixed-integer linear programming (MILP), which includes the practical issues in biomass based energy system such as land use for biomass cultivating, seeding and crop harvesting. In particular, we incorporate a set of new decision variables for the usage of dedicated-energy crops in order to answer the following questions: what and how much energy crop should be utilized for hydrogen supply? And we then conduct a case study of fuel cell vehicles (FCVs) in road transportation sector of future Korea. Based on the proposed model, we identify the optimal configuration including biomass types, occupied lands, the number and location of facilities, and we analysed cost distributions and main cost-drivers.

The result indicates that availability of resource is one of the hard constraint for determining the configuration of B2H2 (Biomass-To-Hydrogen) system, unlike typical hydrogen systems which are mainly derived by a demand satisfaction constraint. For example, most of major B2H2 facilities are located in the biomass-rich regions rather than high-hydrogen-demand regions. The resulted system cost is 2.77$/kg of hydrogen and the main cost-driver is identified as the facility capital cost (41% of total annual cost, 1.13$/kg of hydrogen), followed by feedstock cost (24%, 0.65$/kg) and facility operation cost (16%, 0.44$/kg).

We also analyze the effect of different demands on the total required system cost due to uncertainty of future hydrogen demand. So, we conduct different demand cases (case1 ~ case4). It is revealed that when the demand is lower than base case (i.e. cases 1 and 2), the capital costs of facilities are identified as one of the main cost-drivers. On the other hand, in higher demand cases (i.e. cases 3 and 4), the yield of biomass-to-hydrogen facilities becomes as the key cost factor. The hydrogen demand is also identified as one of the major factor to determine the selection strategy of energy crops for hydrogen production. As hydrogen demand increases, the system utilizes more residues and wastes to meet unsatisfied demand. In the scenario that the demand could not covered by all existing biomass, system is forced to extend the dedicated land for energy crops. In the modest phase (base ~ +17% demand), the energy crops with additional by-product credit and low supply costs are preferred than other types of energy crops. On the other hand, in high hydrogen demand phase (over 17%), the energy crops of a high biomass-to-hydrogen conversion yield are selected as a main feedstock. Moreover, we determined that selecting regions for planting energy crops is strongly affected by the land purchasing cost. It means that the regions which have low purchasing cost are selected sequentially.