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Optimization-Based Design and Analysis of a Complex Energy System with Multiple Renewable Energy Sources

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Extended Abstract

Fossil fuels such as crude oil and coal are currently the primary energy source in the transportation sector. The main challenge on fossil fuels use is the environmental pollutions and climate change by combustion of fossil fuels; the emission of carbon dioxide (CO_2) and other greenhouse gas (GHG) along with other air pollutants.

To meet the challenges of fossil fuels, it is necessary to change current energy system to a new and sustainable system by introducing new high-efficiency technologies into its energy system. And these advanced technologies should be integrated with renewable energy sources (RES) for sustainable energy supply. For instance, advanced vehicles, including electric vehicles (EV) and fuel cell vehicles (FCV), should be fuelled by with zero-carbon alternative fuels such as electricity and hydrogen from RESs. Therefore it is necessary to design a new energy supply system from renewable energy sources (RES) for a sustainable energy system.

To successfully design the RES-based energy system for future transportation sector, we should include various natural energy resources, different technologies for resource harvesting, converting and usage, and different types of energy demand (e.g., electricity, hydrogen and chemicals). The goal of this study is the development of a new approach to assess and analyse a complex energy supply system where a number of types of sources, technologies and demands are included. To achieve this goal, we generate the superstructure of RES-based energy system including different sources (wind, solar, biomass) and technologies (e.g., wind turbine, photovoltaic, electrolysis, and biomass gasification) along with different energy demands.

We develop a new optimization model using mixed-integer linear programming (MILP) to identify the optimal configuration, economic performances and main cost-drivers of the energy supply system. The economic effects of the RES-based energy system depends on the optimal configuration of system. Thus, to be economically viable, which energy sources should be selected for satisfying energy demands with what technology configuration is the challenging question. In the proposed model, various constraints such as demand satisfy, energy flow conservation, limited capacity of technologies are used to subject to the objective function, minimizing the total annual cost which calculates by the total amortized capital cost, the total operating cost, the total material cost and total by-product credit.

We illustrate the applicability of the suggested framework by solving the problem of design of energy supply system in Jeju Island, Korea. As a result, it is identified that wind and biomass-based system (wind turbines, electrolysis, and biofuels production plant) shows the highest economic performance. The wind turbines are used for satisfying the electricity demand and supplying the electricity in electrolysis to produce hydrogen, and take all the hydrogen and fuels from the electrolysis and biofuels plants. It also indicates that key cost-driver in this system is the cost for purchasing biomass feedstock. We also analyse which energy between electricity and hydrogen is more economically feasible for energy storage. It is revealed that as hydrogen demand increases, the stored amount as hydrogen increases while the electricity amount are decreasing and finally reaches to non-use system.