Hybrid Processing of Biomass and Coal with CO_2 Capture for Low Carbon Power Generation

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BY

ASHIM KUMAR KHAN

DEPARTMENT OF CHEMICAL ENGINEERING
JADAVPUR UNIVERSITY
KOLKATA – 700 032
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Abstract

To address twin problems of fossil fuel depletion and environmental degradation due to CO_2 emissions, there is a necessity of energy transition from high carbon conventional resources to renewable low carbon fuels. Biomass is a promising eco-friendly alternative source of renewable energy in the context of current energy scenarios. To explore the possibility of the usage of agricultural and MSW derived lignocellulosic biomass with coal in the Indian power sector, in detail, the present research focused in the following directions: (I) an evaluation of the prospect of a IGCC power plant based on mixture of coal and Agri-MSW-based biomass; (II) assessment of the effect of integration of the mixed-fuel IGCC plant with different types of post-combustion CO_2 capture, namely, solvent-based, algal routes and their combination, (III) evaluation of the effect of integration of biodiesel unit with a mixed-fuel IGCC plant with post-combustion CO_2 capture through algal route. Energy and environmental analyses of all the options (I, II &III) have been performed. The parametric sensitivities of avoidance in CO_2 emissions (ACE) and the energy return on energy investment (EROEI) were analyzed against important system parameters. All the analyses are based on ASPEN Plus® simulation data. At first, a systematic process model using ASPEN Plus® has been developed for a 30 TPD IGCC power plant co-fired by Indian coal and Agri-MSW-biomass mixture. The parametric sensitivity of EROEI and ACE were analyzed with respect to the input variables, Agri-MSW -biomass to coal ratio, gasifier temperature and the ratio of supplied air to that required for complete combustion. Optimization of EROEI and ACE of the Co-fired IGCC power plant was performed using Design Expert software. A systematic process model using ASPEN Plus® was then developed for the optimally operated 30 TPD IGCC power plant co-fired by Indian coal and Agri-MSW-biomass mixture, integrated with monoethanolamine (MEA) -based post-combustion CO_2 capture with and without regeneration of solvent. Next, the ASPEN Plus® model was developed for the same IGCC plant integrated with algal CO_2 capture separately using Chlorella *Vulgaris*, *Nannochloropsi*s *spp* and *Scenedesmus spp*. Energy return on energy investment (*EROEI)* was also calculated for the IGCC plant integrated with solvent-based and algal CO_2 capture considering the use of a) in-house power and b) grid power. *EROEI* was calculated for the 30 TPD co-fired IGCC plant integrated with a hybrid system of solvent based CO_2 capture and algal CO_2 capture and utilization considering the use of a) in-house power and b) grid power. Among all CO_2 capture options, EROI of the IGCC plant integrated with hybrid system of CO_2 capture achieves the highest value. Finally, EROEI for an integrated IGCC-algal CO_2 capture unit, coupled with biodiesel production, was also determined considering the use of a) in-house power and b) grid power. For In-house power consumption option, there is a marked increase in the EROEI values with the integration of biodiesel unit. This is due to the consideration of substitution of a part of energy from product biodiesel. The outcome of this research is expected to be useful in taking strategic decisions on running IGCC power plants using a

combination of coal and Agri-MSW based biomass as feed. It is expected that the assessment of performance of energy return and CO_2 avoidance of different CO_2 capture and utilization units will further facilitate the implementation of the plan of Government of India to use biomass along with coal in the power generation sector.