Process Design and Analysis of Ethylene and Propylene Manufacturing from Shale Gas

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Abstract

Ethylene and propylene are important building blocks for the manufacturing of plastics, fibers, and other chemicals. Primary feedstocks for olefins manufacturing industry includes natural gas liquids (NGLs, ethane, propane, butanes, etc.), naphtha, gas oil, etc., which are produced from natural gas processing or crude oil processing. In recent years, advances in directional drilling, hydraulic fracturing, and microseismic monitoring technologies have led to a boom of shale gas production in the U.S., which provides extra ethane and propane as feedstock alternatives for manufacturing ethylene and propylene. As a result, the U.S. ethylene industry is shifting feedstocks from naphtha to lighter hydrocarbons, such as ethane and propane. However, since ethane cracking results in much lower propylene yields than naphtha cracking does, the shift in feedstocks for ethylene production leads to a propylene gap in the U.S. Benefiting from the availability of propane fractionated from shale gas, propane dehydrogenation as an on-purpose propylene production technology has been an attractive chemical route. Costs and environmental impacts of olefins produced from shale gas have drawn particular attention from both industrial and academic areas. Techno-economic and environmental analysis was conducted to decipher production costs and environmental impacts of ethylene produced from shale gas. With different feedstocks and technologies, concerns come on which pathway is more competitive regarding economics and environmental impacts. However, systematic comparisons of different olefins production pathways are not considered in existing contributions, and thus these concerns are not completely addressed.

In this work, we perform a comparative techno-economic and environmental analysis for manufacturing ethylene and propylene from wet shale gas and naphtha. Depending on the steam cracking technology and propane dehydrogenation technology, two pathways for producing ethylene and propylene from wet shale gas are considered. In the co-cracking pathway, raw shale gas is processed to produce the ethane-propane mixture, which is then stream co-cracked to manufacture ethylene and propylene. In the technology integrated pathway, ethylene is mainly produced via the steam cracking of ethane, and propylene is
mostly manufactured via the dehydrogenation of propane. For the purpose of systematic comparison, we also take into account a naphtha cracking pathway in which ethylene and propylene are co-produced via the steam cracking of naphtha. The shale gas processing and olefins production processes are modelled and simulated in Aspen HYSYS to obtain the mass and energy balances. On this basis, economic and environmental performances of different olefins production pathways are explored and compared. Given the same ethylene production rate, the mass balance shows that the technology integrated pathway produces more propylene than the naphtha cracking pathway. This means the technology integrated pathway is able to substitute for the naphtha cracking pathway for ethylene and propylene production. The economic analysis indicates that costs for ethylene and propylene produced via the naphtha cracking pathway are nearly 1.8 times of that produced via the co-cracking pathway and 2.1 times of that produced via the integrated pathway. Manufacturing ethylene and propylene from wet shale gas is more cost-effective. However, the technology integrated pathway and the co-cracking pathway result in higher life cycle GHG emissions than the naphtha steam cracking pathway by roughly 40% and 20%, respectively.