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Subject Area	Energy and Environment

Economic Optimization of a Hydrogen Production System with Methanol as Feedstock

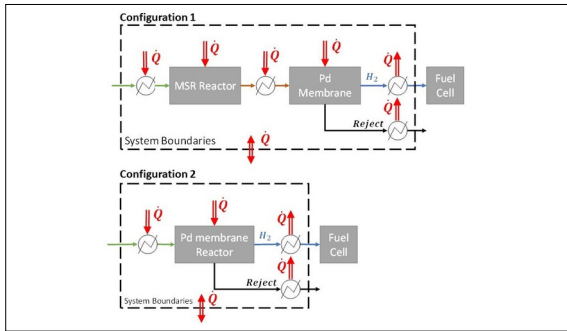


Fig. 1: Diagrams showing the two considered configurations

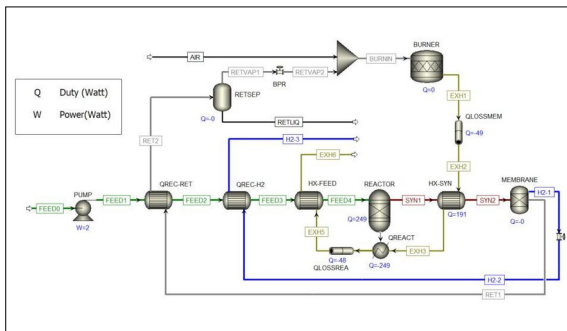


Fig. 2: The hydrogen production system was modeled using the simulation software Aspen Plus

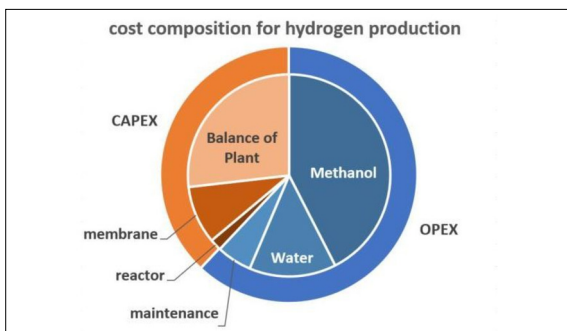


Fig. 3: The investigation of the cost shares led to a better estimation of the saving potentials

Introduction: At the South African Institute of Advanced Material Chemistry (SAIAMC) at the University of Western Cape (UWC) in Cape Town, one emphasis is the development of Pd membranes for hydrogen separation. The only compound permeating through palladium is hydrogen, so Pd membranes are capable of reaching a highly selective hydrogen separation. The separated hydrogen can have a purity of more than 99.9999 %¹. Today, the industrial hydrogen production is mainly based on steam reforming of hydrocarbons and alcohols. The purification of the hydrogen is complex and involves several reaction steps. If it is possible to produce a Pd membrane that has a high long-term stability, the costs and complexity of hydrogen production can be significantly reduced.

Objective: In this work, a hydrogen production system based on a methanol steam reforming reactor (MSR reactor) and a Pd membrane as a possible application was economically analysed. Process integration and finding the optimal operating conditions were integral parts of this work. To reach these targets, a model was built using the simulation software Aspen Plus. Furthermore, two configurations shown in Fig. 1 were studied: A first approach analysed a system where the hydrogen separation was done after the reactor. In the second configuration, the Pd membrane was integrated in the MSR reactor in order to continuously remove the hydrogen along the reactor (membrane reactor). This way, the product formation was enhanced as the reaction can proceed beyond its equilibrium.

Result: Fig. 2 shows the final flow sheet of configuration 1 as the result of the process integration. The heat of the hydrogen output stream and the reject stream is recovered by preheating the feed. The remaining heat requirement is supplied by burning the reject that still contains hydrogen. The efficiency increase by water condensation does not lead to a significant cost reduction, but the condensation enables water recycling, which decreases operational costs. Fig. 3 shows that the costs for the membrane are higher than those for the reactor. The high share of balance of plant expenses is due to the small system size, it is intended to feed a 1 kW_{eI} fuel cell. The operational costs were decreased by the water recycling, but they still make up more than half the costs. However, compared to other technologies the capital costs have a relatively big share in the analysed system. It was shown that the advantages of the membrane reactor (configuration 2) are smaller than expected. Methanol steam reforming already has a high hydrogen yield at its equilibrium, so no big gain resulted in the integration. Furthermore, a bigger membrane surface than in configuration 1 was required, which led to higher costs. As mentioned, the membrane costs are higher and therefore more significant as the reactor costs, so the cost reduction of the catalyst size did not compensate the bigger membrane.¹ N. Al-Mufachi et al., "Hydrogen selective membranes: A review of palladium-based dense metal membranes," Renewable and Sustainable Energy Reviews, vol. 47, pp. 540-551, 2015.