Deliverable 11: Executive summary

In this report the reactor concept for a membrane reformer is selected. This membrane reformer is a specific type of membrane reactor that is used for conversion of natural gas into a hydrogen and carbon dioxide. The H_2 stream can be then be used for power generation. A separate CO_2 stream becomes available for underground storage. A second application of the same reactor is the more efficient reforming of natural gas for generation of hydrogen for application in industrial large-scale ammonia production.

The membrane reactor working principle is depicted in Figure 1.

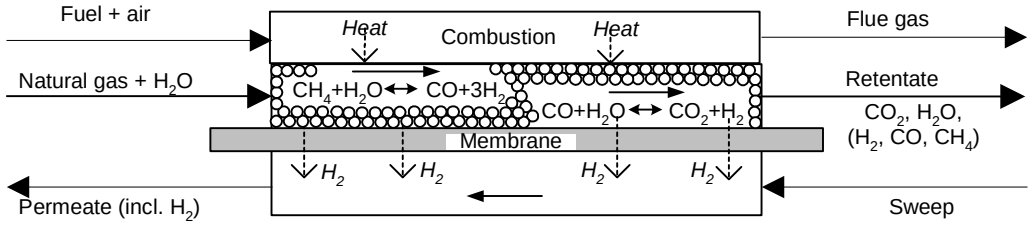

Figure 1: *Membrane reactor working principle*

The feed of the membrane reactor is a mixture of natural gas and steam, which could already be partly converted in a pre-reforming step. The reactions are the methane steam reforming reaction and the water gas shift reaction.

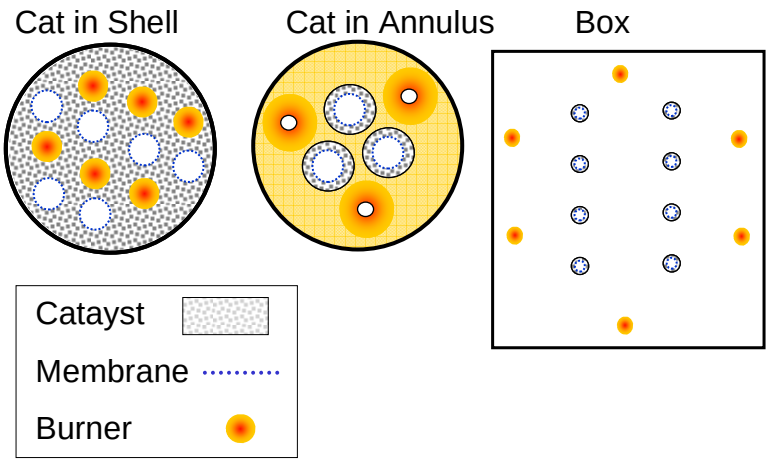

Figure 2: *Top view of the three selected concepts*

In earlier work a total of nine concepts for a membrane reactor have been generated. From the long list of nine concepts three concepts were selected for further analysis. Figure 2 gives the top view of the three concepts. The 'cat in shell' concept is a membrane reactor based on a shell and tube heat exchanger where shell is filled with reforming catalyst. A part of the tubes is replaced by membrane tubes and the other tubes by heating tubes. In the 'cat in annulus concept' the catalyst is placed in an annular tube surrounding the membrane tubes. The heating zone is now in the shell. Finally the 'box' concept is depicted which is based on a conventional steam methane reformer. It consists of an atmospheric box with heaters. In the box reformer tubes are placed with membrane tubes placed inside them. Catalyst is in the annular zone between the membrane tubes and reformer tubes. In the box concept

manifolding is based on an approach using headers and pigtails, rather than a multiple tube sheet approach as in the other concepts.

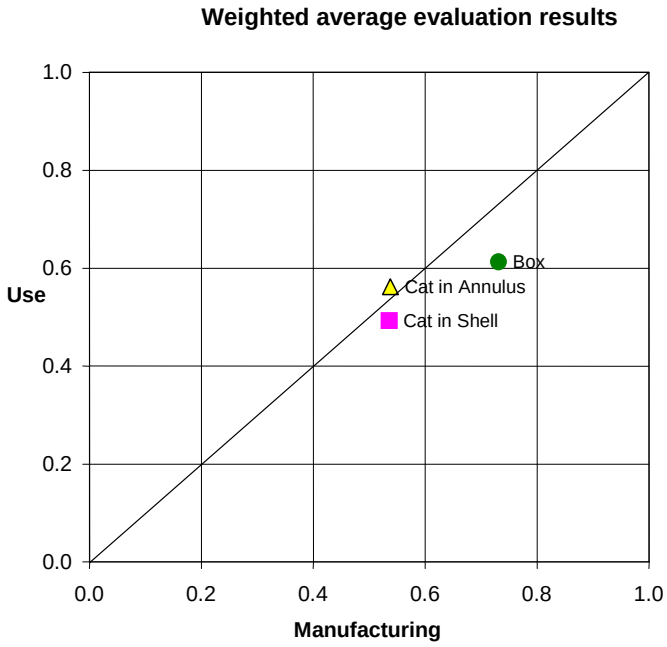

Figure 3: *Weighted averaged results of the panel evaluation of membrane reactor alternatives*

The three concepts have been assessed by an expert panel using a a multi-criteria analysis. The selection was for a full scale application of a membrane reactor for CO_2 capture at a gas fired power plant. The panel was supplied with input from design studies. The result of the multi-criteria analysis is depicted in Figure 3. The best scoring concept (closest to the right upper corner) is the 'Box' concept.

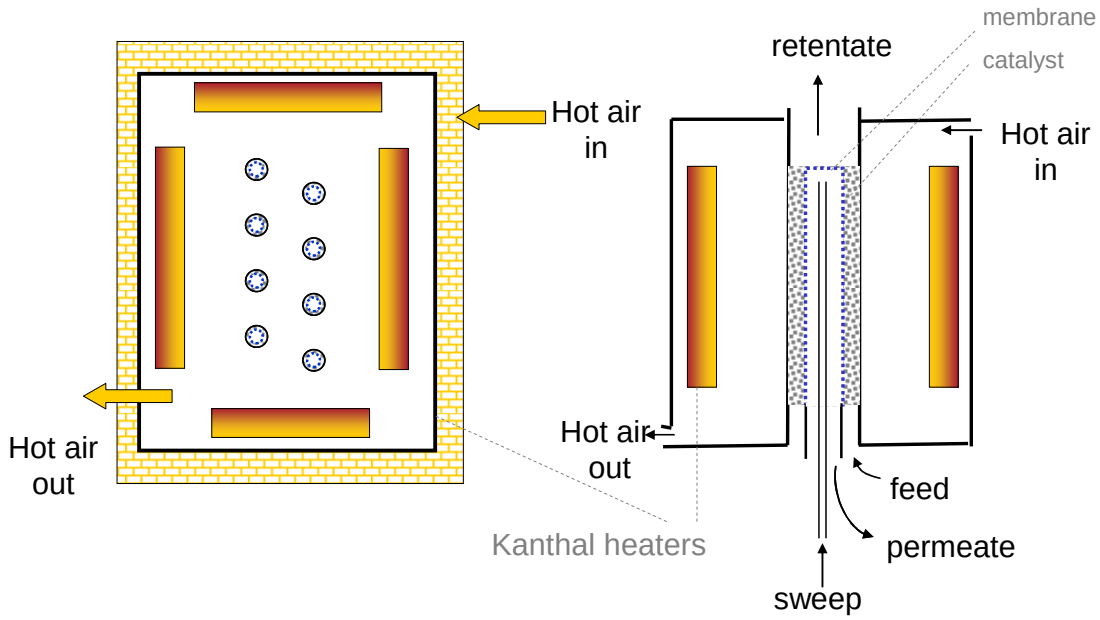

Figure 4: *Concept design of PDU membrane reactor. Top (left) and front (right) view.*

The full scale concept has been translated into a concept design for a bench scale process development unit (PDU). The PDU design is depicted in Figure 4. The burners will be replaced by a combination of electrical heating elements (Kanthal heaters) and electrically heated air. A total number of 8 membrane tubes of 50 cm length will be placed in the reactor. The maximum reactor operating temperature will be 600° C, maximum pressure 40 bara. At the nominal temperature of 500° C the membrane reactor will process a total of 0.4 l_N/s of a pre-reformed natural gas/steam mixture (S/C=3) having a hydrogen recovery of about 80%.