Future Energy Plants, Co-production of electricity and hydrogen with integrated CO_2 capture

Project duration: 2001-2005
Budget: 29 MNOK
Funding by: Norges Forskningsråd, Klimatek-programmet
Project manager: Institute for energy technology (IFE)
Main partners: CMR Prototech and CMR instrumentation

The four-year program was subdivided into three different parts:

- Sorption enhanced methane steam reforming (integrated reforming and CO_2-capture) and reactor technology (IFE).
- SOFC technology and system design (CMR Prototech)
- Supporting technologies (CMR Instrumentation)

A Solid Oxide Fuel Cell (SOFC) operating at high temperature converts natural gas into electricity and is also a valuable heat source. In addition, the energy efficiency can be considerably increased compared to e.g. combined cycle gas and steam turbines, and use of SOFCs also allows energy efficient capture of CO_2.

The most common industrial process to produce hydrogen is to react methane with steam followed by a purification of the hydrogen stream. Steam methane reforming (SMR) of natural gas is a complex process consisting of several process steps.
In the present concept, hydrogen is produced from natural gas and water in an improved, simplified reforming reaction utilizing the conversion of a metal oxide (MetO, e.g. CaO) to metal carbonate (MetCO$_3$, e.g. $CaCO_3$). The carbonate is decomposed thermally in a separate reaction to release the CO_2, and the metal oxide is recycled. This provides an efficient mean for separation of the carbon dioxide for use or storage. The exothermic carbonation reaction allows for production of hydrogen at lower temperatures than in the conventional process and higher hydrogen yields are also obtained.

In the present program, the basic idea is to use the waste heat from a solid oxide fuel cell (SOFC) in the hydrogen production.

The present gas power concept (the ZEG-technology) then produces both electricity and hydrogen with integrated CO_2 capture, and the CO_2 is delivered as a pure pressurised stream ready for industrial use or storage.

The identified main challenges of the concept are:

- The heat transfer and thermal integration of the SOFC and the reactors for hydrogen production/absorbent regeneration in order to obtain high overall efficiencies.
- The absorbent capacity, stability, lifetime and multi-cycle properties.
- The reactor technology; design and development of a reactor for the reforming and calcination reactions, in a batch process with several similar fixed bed reactors where gas atmospheres are shifted, or in a continuous process using a dual circulating fluidized bed system where solids are moved between the two reactors.

During the first year of the project, four different possible concepts for integration of the SOFC and the reactor(s) for hydrogen production were identified, with a concept called ZEG-4 “the SOFC with hydrogen recycle” (Figure 1) as the most novel and efficient concept.

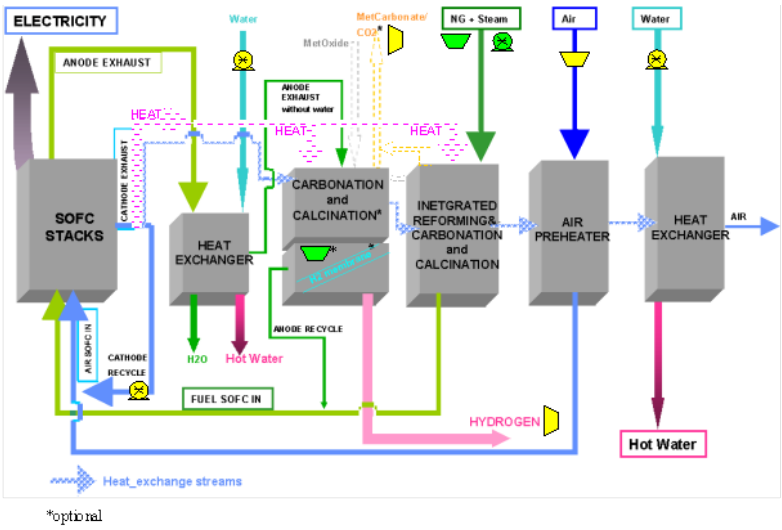

Figure 1 ***ZEG***®*; “The SOFC with hydrogen recycle”*

The process comprises a SOFC power plant operated on high throughflow of hydrogen in a hydrogen recycle loop. Water is continuously removed from the recycle loop. The natural gas is reformed in an integrated SE-SMR unit producing hydrogen both for the SOFC power plant and for the hydrogen market. The system also includes a calcination reactor for regeneration of CaO and CO_2 desorption. All the CO_2 comes from the calcination reactor. The system does not include an afterburner, as the fuel utilisation is 100%. The system has a theoretical electrical and a total efficiency approaching 100%, only limited by balance of plant (BOP) losses.

The concept has a high potential with respect to electrical and overall efficiencies, about 80 and 90% respectively, as illustrated in Figure 2.

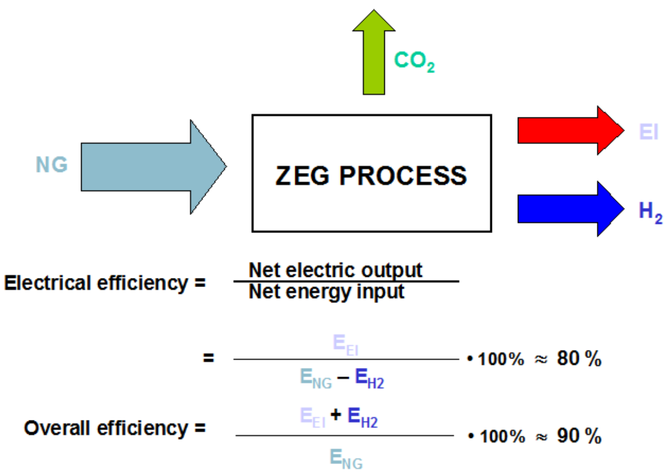

Figure 2 Energy efficiency of ZEG-concept

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