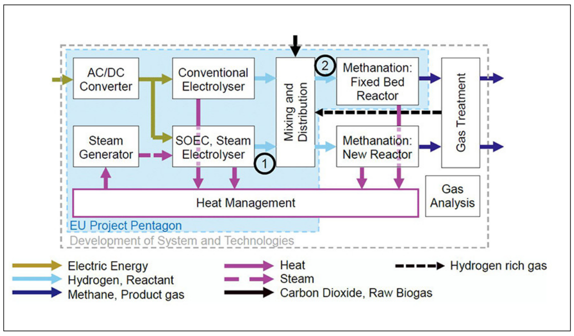
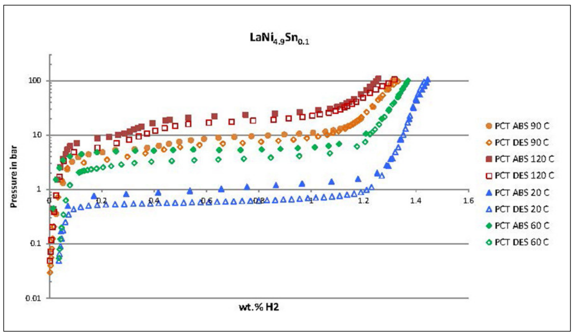
Fabian Ruoss

Graduate Candidate	Fabian Ruoss
Examiner	Prof. Dr. Markus Friedl
Co-Examiner	Prof. Dr. Mykhaylo Lototskyy, University of the Western Cape (UWC), Bellville
Subject Area	Energy and Environment

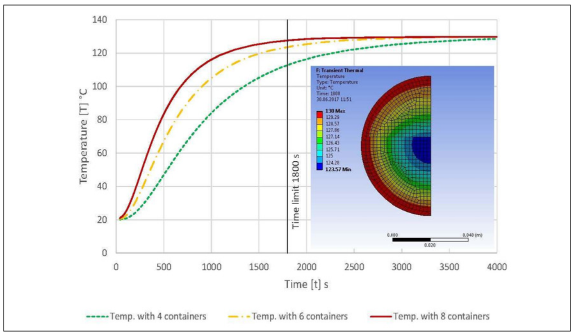
Metal Hydride Compression of Hydrogen in a Power-to-Methane plant with integrated SOEC



Block diagram of the new Power-to-Methane plant.



Pressure-composition isotherms for different absorption and desorption temperatures for the LaNi4.9Sn0.1 sample.



Results of the transient thermal FEM simulation.

Introduction: The substitution of fossil fuels is an important task when it comes to reduction of the CO2 emissions. Today it is possible to produce synthetic fuels like methanol or methane from water and CO2. For this purpose water is split into hydrogen and oxygen by electrical energy using electrolysis. CO2 can be captured from flue gas or directly from the atmosphere. If the electrical energy is generated, using renewable sources like solar or wind, the produced synthetic fuels may then be considered as renewable. However the production of synthetic fuels from renewable energy is generally not economical using today's technologies. One way to reduce the production costs of synthetic fuels is an increase of the efficiency of the conversion.

Objective: The Institute for Energy Technology is building a new Power-to-Methane plant with the goal to increase the efficiency from today 50 % to 70 % (H_HV/P_AC). This is done by using a SOEC instead of a conventional water electrolysis. The SOEC is not able to generate a pressure above 1.01 bar at the hydrogen outlet. This is not enough to operate a methanation reactor properly due to the reaction's thermodynamic equilibrium. To increase the hydrogen pressure a Metal-Hydride-Hydrogen-Compressor (MHHC) should be used to increase the pressure to 10 bar. A MHHC is powered by waste heat instead of electricity. This decreases the total electrical energy consumption of the plant. In this thesis a concept was developed to compress 2 Nm3/h from 1.01 to 10 bar using waste heat from the reactor. The thesis showed that it is possible to compress hydrogen using waste heat with an isothermal efficiency of 5 %. Accounting for the fact that waste heat is used, an exergetic efficiency over 21 % is possible. In order to find a suitable metal hydride, four metal hydride samples have been prepared. The four samples were tested and a desorption pressure above 10 bar at 120 °C was reached. However the cycle productivity of the samples was limited by the low absorption pressure of 1.01 bar at 20 °C. The best cycle productivity within this conditions was reached with LaNi4.9Sn0.1 with 0.031 m3/kg. Due to the low cycle productivity the required mass for the compression of 2 Nm3/h hydrogen is 91.7 kg. Therefore power demand of 2.2 kW is required. The available amount of waste heat is limited at 0.388 kW because of steam production for the SOEC. Using a more suitable metal hydride where the whole reversible storage capacity is available at 1.01 bar the specific energy demand could be decrease by a factor of 3. A cost analysis for a Power-to-Methane plant with integrated SOEC showed that the use of a MHHC could reduce the total electrical energy consumption of the plant by 3.6 % decreasing the methane production cost by 1.6 %. However, the integration of a MHHC in a Power-to-Methane plant with a SOEC is only advantageous if an additional source of waste heat is available.