Why Fuel Cells?

Fuel cells have shown great promise for use in residential micro-Combined Heat and Power (mCHP) generation due to their high electrical efficiency and ability to run on conventional heating fuels, but high capital costs remain a key challenge to the advancement of this sector and mass market introduction in Europe.

About HEATSTACK

This 36-month project, funded through the FCH Joint Undertaking and Horizon 2020, is focused on reducing the cost of the 2 most expensive components within the fuel cell system – the fuel cell stack and heat exchanger – which together represent the majority of total system CAPEX. The project has partners in 5 EU countries.

Senior Flexonics UK, based in Crumlin (Wales), provide expertise in the design, development and manufacturing of heat exchange solutions for the energy generation market and for land vehicle applications including electric vehicles. Senior's manufacturing facility in Olomouc (Czech Republic) covers 3630m² and is equipped for production of Turbo Oil Drain and Turbo Oil Feed tubes for passenger car engine manufacturers, and volume production of Cathode Air Pre-heaters (CAPH) working at up to 950°C and a 1000°C peak.

The Centre for Hydrogen and Fuel Cell Research at the University of Birmingham's School of Chemical Engineering is internationally recognised for its dynamism and expertise in Fuel Cell Technologies. The Centre focuses on R&D, applications and demonstrations of Hydrogen and Fuel Cell systems; it has numerous publications and patents in Fuel Cell Technologies, as well as state-of-the-art facilities.

ICI Caldaie is a leading company of the CHP sector thanks to the continuous R&D of highly reliable heating generators keeping up with the technological evolution, which has allowed the firm to transfer the know-how acquired in the planning and realization of industrial steam generators, a sector in which the firm occupies a leading position.

Vaillant is one of the market leaders and technological pace-setters within the heating, ventilation and air-conditioning industry. Vaillant's product portfolio encompasses highly-efficient CHP appliances based on gas engines for the use in single- or multi-family homes that represent today's most efficient gas technology.

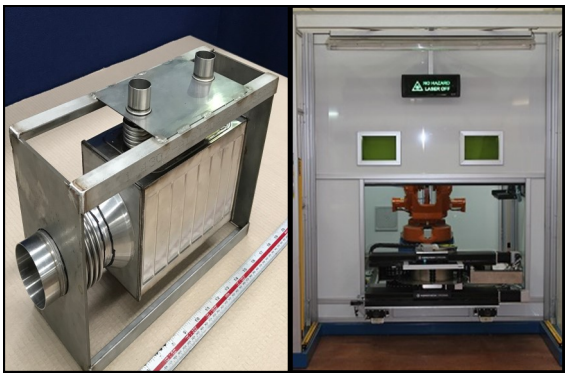
Sunfire develops and produces high-temperature fuel cell (SOFC) and electrolyser (SOEC) systems, which address a multitude of problems in energy systems. Their SOC technology has been perfected to achieve the optimal balance between high reliability, low manufacturing costs, high electrical efficiencies and reversible operation.

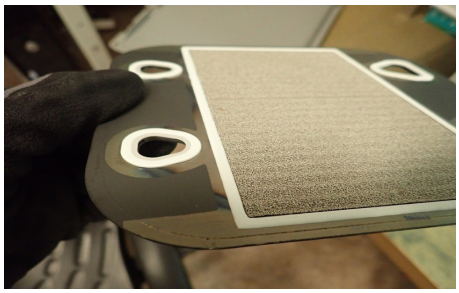
The PNO Group is a pan-European innovation consultancy with offices in The Netherlands, Belgium, France, Germany, Italy and the UK. Working across all principle industry sectors, PNO has developed extensive expertise in establishing, managing and contributing to complex international technology transfer consortia, communities, processes and projects.

This project has received funding from the Fuel Cells and Hydrogen 2 Joint Undertaking under grant agreement No 700564. This Joint Undertaking receives support from the European Union's Horizon 2020 research and innovation programme and Hydrogen Europe and N.ERGHY.

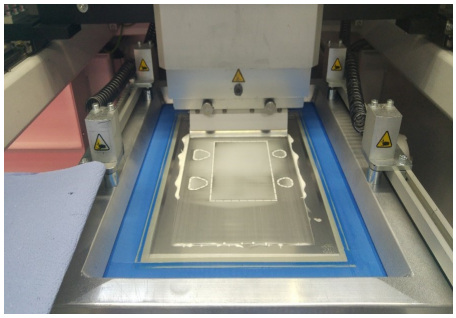
Project achievements

- Senior Flexonics has a **production-ready CAPH** using AluChrom that gives **robustness, cost effectiveness** and **industry leading low levels of Cr leakage**.
- Significant investment has been made in equipment and tooling to achieve process efficiency.
- Simulation has allowed the development of a **design that can be used in different applications**, which functions at different temperatures, pressures and flow rates, within the boundary condition range of project partner ICI Caldaie's specifications.





- **Printing of the glass seals** was chosen by Sunfire out of six alternatives as the method with the **best value** for industrial stack production.
- Devices needed for printing have been designed and built.
- 2 printing slurries have been developed during the project.
- The **first printing tests showed good results** achieved for thin layers.



- A **denuder technique** was employed by the University of Birmingham to quantitatively analyse the chromium vaporisation from Inconel 625 & AluChrom 318.

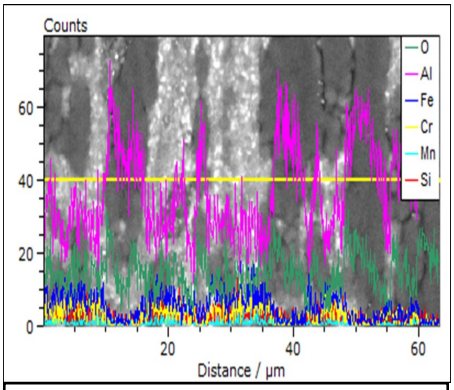


Figure: EDX line scan from steel through the oxide scale of AluChrom 318 after 1000 hours exposure at 850 °C in air containing 3% H_2O (6.0 L/min).

- The Cr evaporation rate for AluChrom 318 is approximately one order of magnitude lower than that for the Inconel 625.
- The formation of a dense and continuous alumina scale on the alloy surface could effectively reduce the high temperature Cr leakage in the long term.
- The **low cost, low Cr evaporation, and excellent high temperature corrosion resistance offered by AluChrom 318 make it highly suitable for CAPH application**.

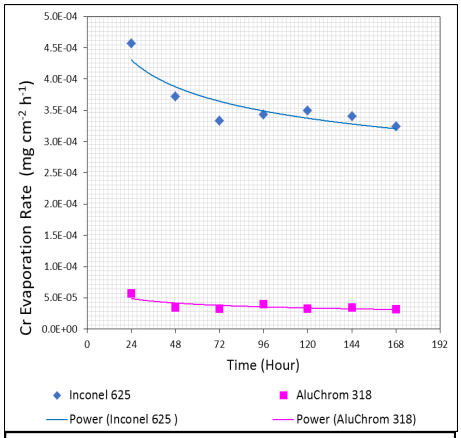
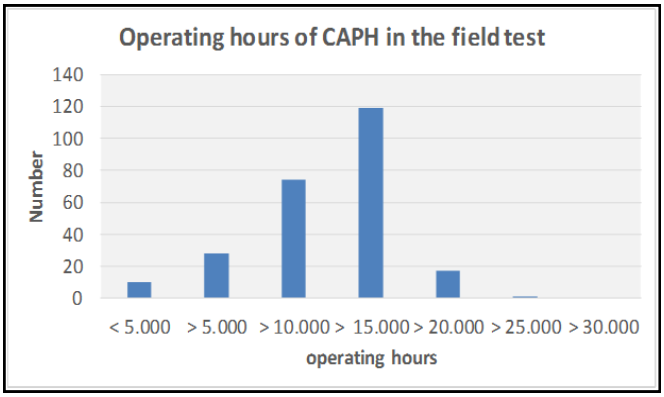


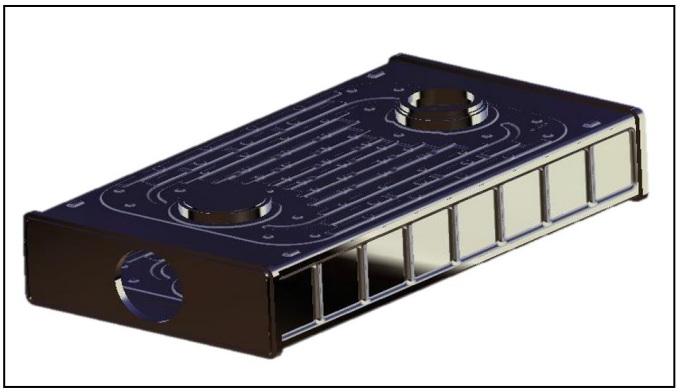
Figure: Rate of Cr evaporation as a function of time for Inconel 625 and AluChrom 318 at 850 °C in air containing 3% H_2O (6.0 L/min).

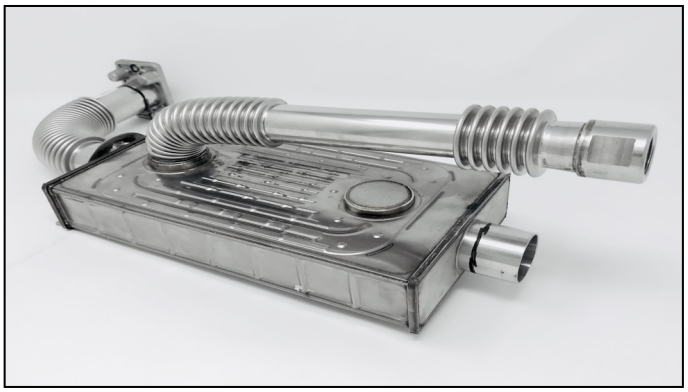
- The **results for operating hours from Vaillant's field testing are positive for HEATSTACK**.
- This field testing (from 2013 to April 2017) totals **over 3.4 million operating hours**.
- The maximum single CAPH operating time with Inconel so far is 28,600 hours.
- The maximum single CAPH operating time with Aluchrome so far is 19,700 hours.



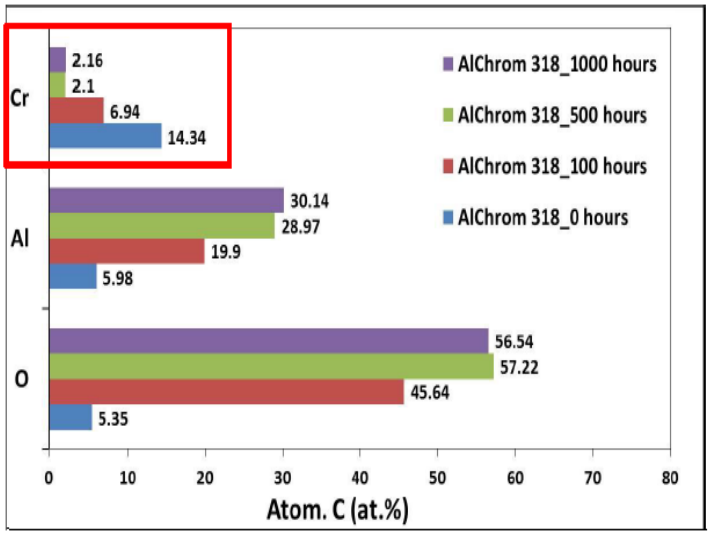
Project achievements

- Senior Flexonics' **patent-pending CAPH** has a contra flow design that can work up to 1000C, **proven effectiveness of over 90%** and very low pressure drop for both fluids.





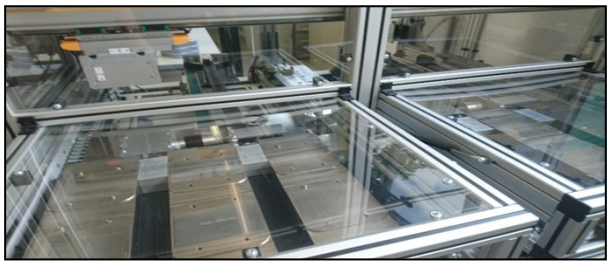
- University of Birmingham have shown through applied research that **AluChrom has improved Cr leakage rates when compared to all other materials after just 150 hours**.
- With Inconel, Cr oxide forms on surface and remains there.
- SS 309 also forms Cr oxide, which spalls and breaks from surface.
- Aluminised SS309 loses Alumina surface and is replaced by Cr oxide.
- Having **Aluchrome surface reduces Cr oxide content and increases Alumina**



- ICI Caldaie have integrated the Senior Flexonics heat exchanger prototypes into their test rig, with adaptations to the fume line in order to **test in the widest range of conditions possible** and to **improve the quality of the data** collected.

- ICI monitored the prototypes over the testing period, which ran into the final year of HEATSTACK, so that a thorough evaluation of performance could be conducted.

- Sunfire continued development of **fuel cell stack production processes,** with laser measurement in operation and a first design of the core unit completed.



- Sunfire also continued working on **process automation development**, with a first line design now completed.