



LARGE-SOFC - Towards a Large SOFC Power Plant

LARGE-SOFC, Towards a Large SOFC Power Plant

R. Rosenberg, J. Kiviaho, J. Göös, P. Jansson, O. C. Tarnowski, J. Jacobsen, L. Blum, R. Steinberger-Wilckens

Fuel Cell Seminar 2009



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Background

- ∅ European Fuel Cells and Hydrogen Joint Undertaking has established a target of 8-16 GW installed fuel cell power in 2020
- ∅ This is to be covered by a number of residential 1-2 kW units, 10-1000 kW industrial units and \geq MW stationary power plants
- ∅ The residential systems will be either PEFC or SOFC. Several European producers exist
- ∅ The industrial units and stationary power plants will be either MCFC or SOFC. Ansaldo and MTU are producers of MCFC systems
- ∅ Two European companies develop large SOFC systems. RRFCS develop stacks and whole systems while Wärtsilä is system integrator with TOFC as SOFC stack producer



Large-SOFC, an EU Integrated Project

- ∅ The European Commission is co-funding the project in order to support the industry in its efforts to develop commercial SOFC stationary power plants
- ∅ Duration of project is three years 2007-2009
- ∅ Budget 11 M€ of which commission grant 5.8 M€

- ∅ **The aim of the project is to address the basic problems when moving from kW to MW size SOFC power plants**
- ∅ **Development and verification of**
 - **Concepts**
 - **Components**
 - **Sub-systems**

- ∅ Long term goal of the development
 - **Commercial life time and cost**
 - **Electrical efficiency up to 60%, CHP efficiency >80%**

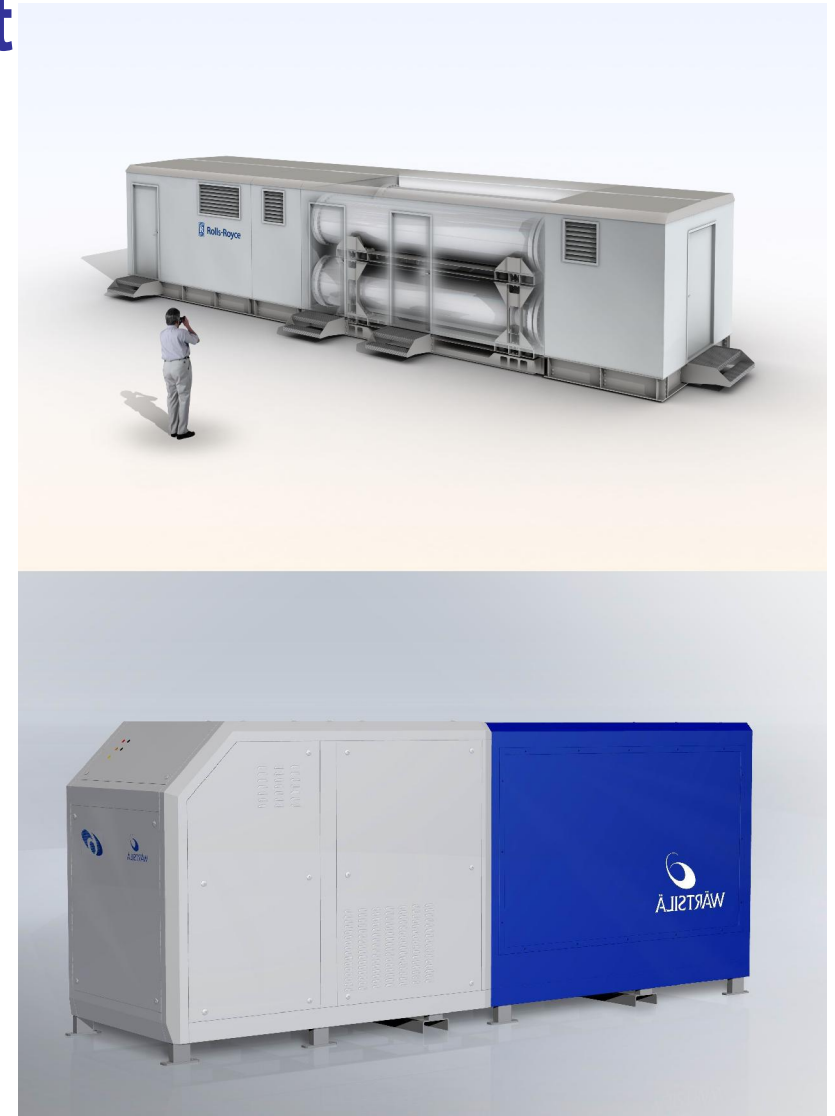


Participants

| | | |
|--|----------|----|
| VTT Technical Research Centre of Finland | VTT | FI |
| Wärtsilä Finland | Wärtsilä | FI |
| Rolls-Royce Fuel Cell Systems Ltd | RRFCS | UK |
| Topsoe Fuel Cell A/S | TOFC | DK |
| Forschungszentrum Jülich GmbH | FZJ | DE |
| Dipartimento di Ingegneria Chimica e di Processo "G.B. Bonino" - Università di Genova | UNIGE | IT |
| BOSAL RESEARCH nv | Bosal | B |
| The Switch Oy | Switch | FI |
| Inmatec Technologies GmbH | Inmatec | DE |

Target design to be developed: parallel development

- ∅ SOFC technology has two main streams, atmospheric and pressurised - each have specific features and advantages.
- ∅ Both technologies have applications to future power generation needs
 - ∅ Hybrids for ultimate electrical efficiency & multi MW range.
 - ∅ Atmospheric 0,5 – 5 MW CHP applications in distributed generation.





Components and subsystems

The objective is to develop new and test commercially available components and sub-systems which need to be

- Ø Efficient
- Ø Effective
- Ø Affordable

The components are

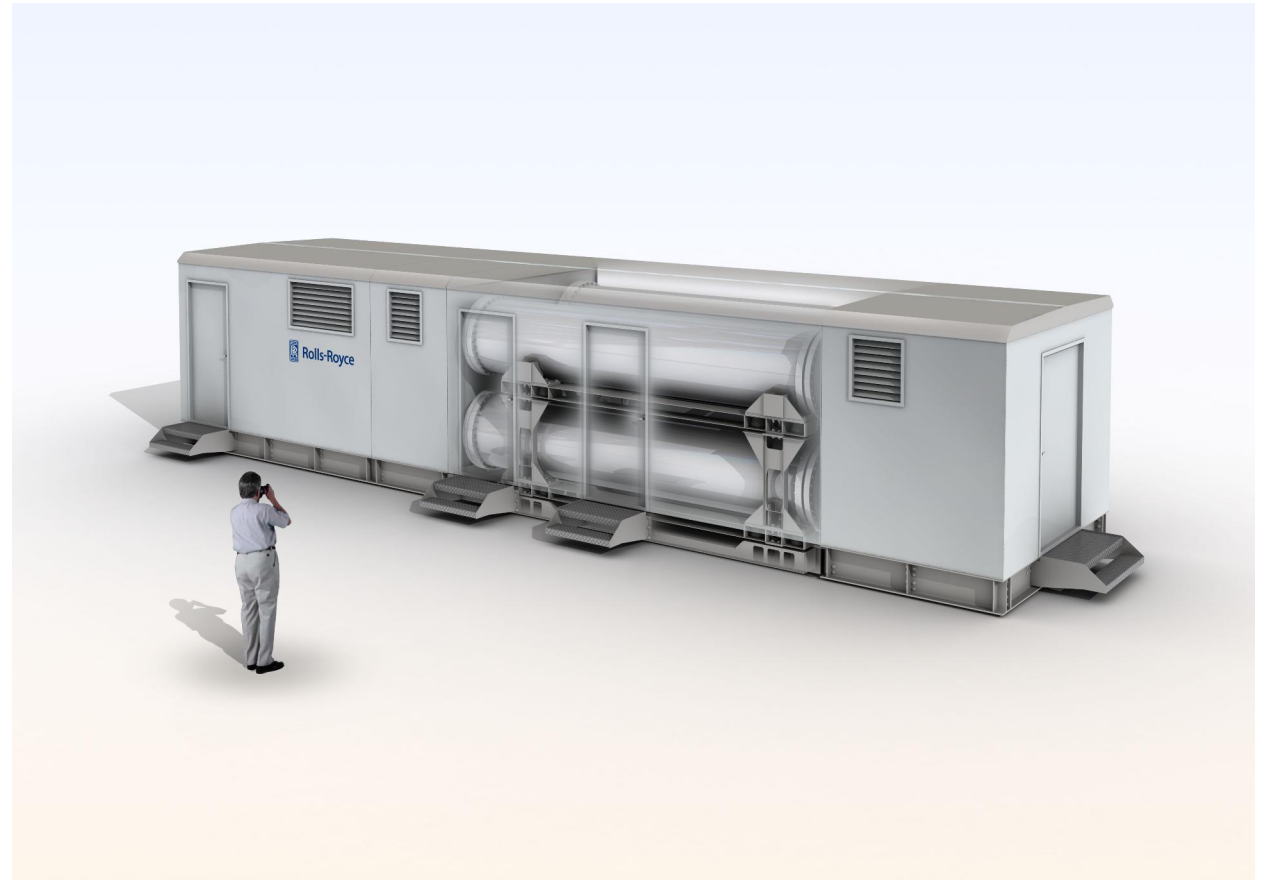
- Ø Combustor equipment for start-up and stack off-gas burning.
- Ø Fuel and air re-circulation equipment.
- Ø Heat exchanges and recuperators
- Ø Fuel processing equipment for normal operation, start up and fuel flexibility.
- Ø Power electronics and control systems



Pressurized system of RRFCS

Ø1 MW comprising
four 250 kW stack
units.

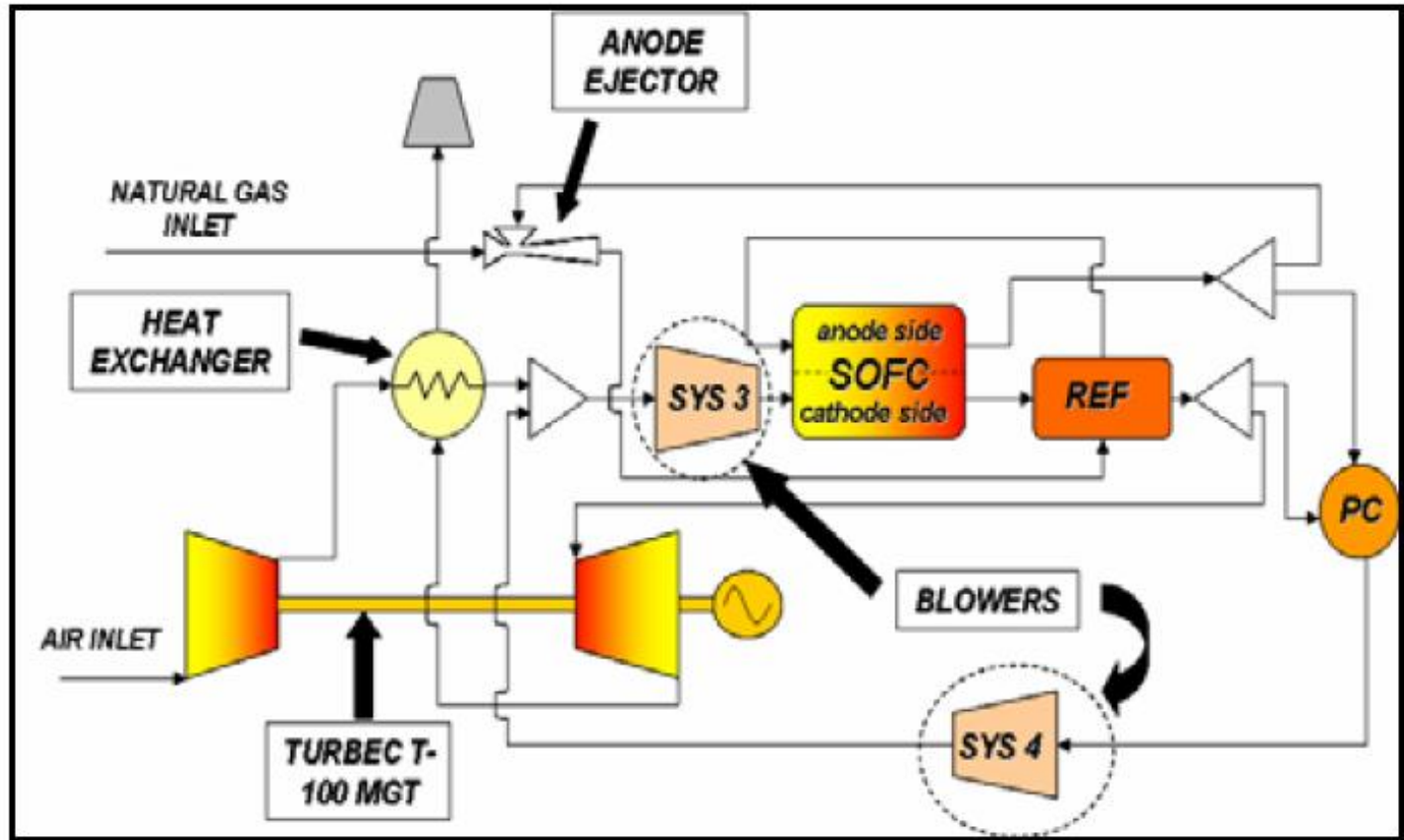
Ø Target is cost
optimisation with
minimum
components



New pressurized system concept

Ø New concepts replace cathode ejector with blowers and original bespoke microturbine with Turbec 100:

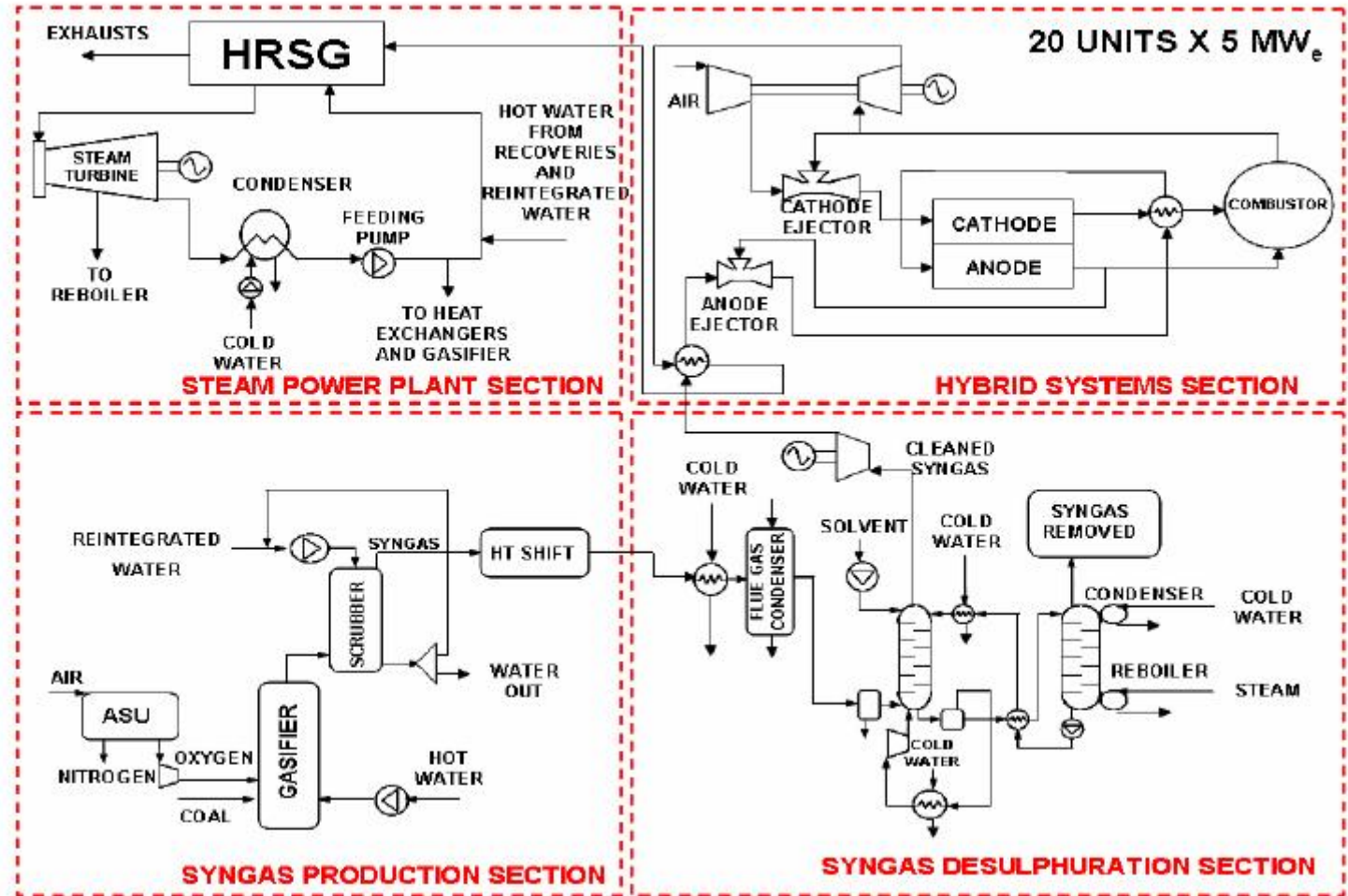
Ø 55% electrical efficiency increases to almost 60%.





Large SOFC including gasification of coal and carbon capture and storage (CCS)

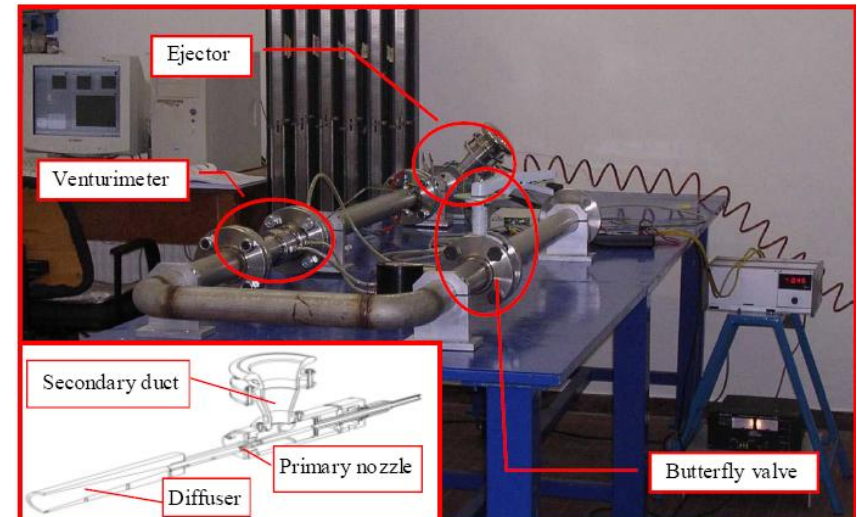
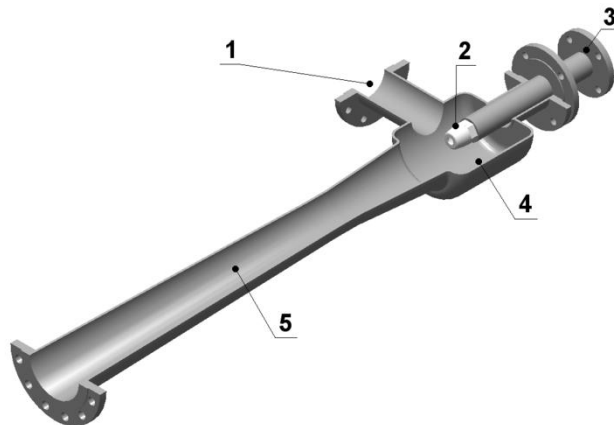
- Ø 20 units of 5 MW
- Ø Electrical efficiency 41% with CCS and 47% without CCS
- Ø In comparison Integrated Gasification Combined Cycle (IGCC) plant: 31% with CO₂ capture



Turbo machinery, gas and air circulation

University of Genoa test facilities are used to

- Ø Analysis of anode and cathode recirculation devices
- Ø Flu dynamic interaction between micro turbine and stack
- Ø Micro turbine control strategies
- Ø Validation of models



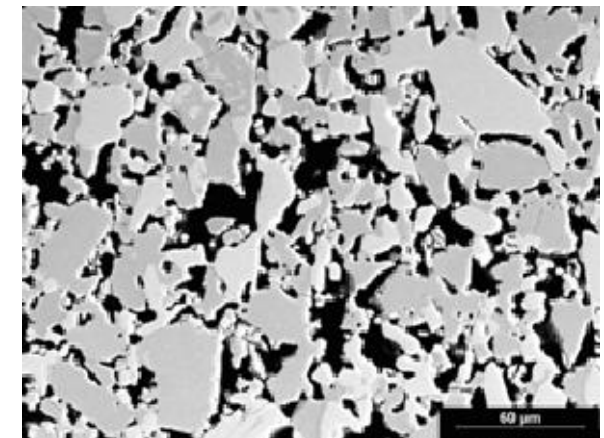
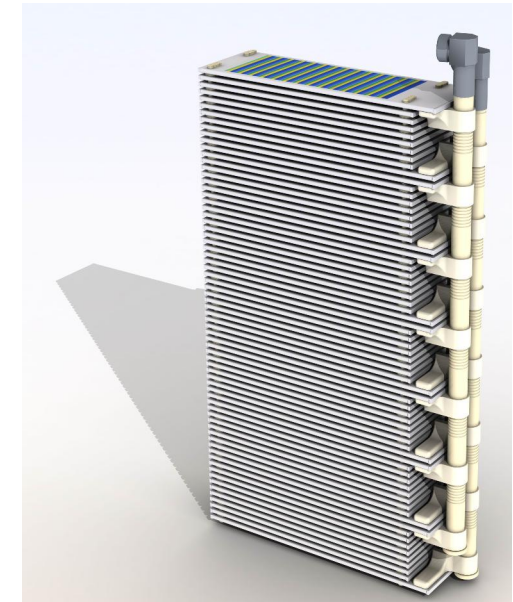
Heat exchangers and recuperators.

- Ø The goal is the analysis of heat exchanger materials in order to optimise heat exchanger corrosion properties and cost
- Ø Bosal developed test stands for testing metal materials for heat exchangers
- Ø Mechanical properties including creep tests and chemical stability for a number of materials have been performed



Ceramic materials for pressurized stack

- ∅ New cost and performance optimised ceramic support materials are developed taking into account
- ∅ Thermal expansion
- ∅ Gas permeability
- ∅ Chemical compatibility
- ∅ Stability at temperatures
- ∅ Low cost



Non pressurized 50 kW system

To take into account:

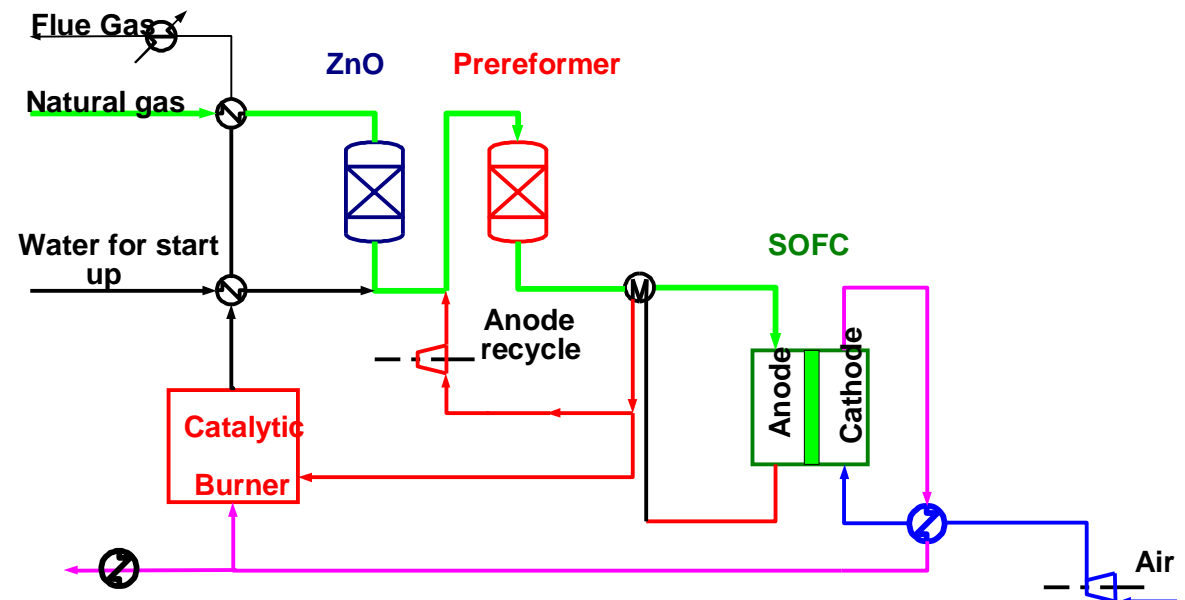
Ø Efficiency

Ø Reliability

Ø Maintainability

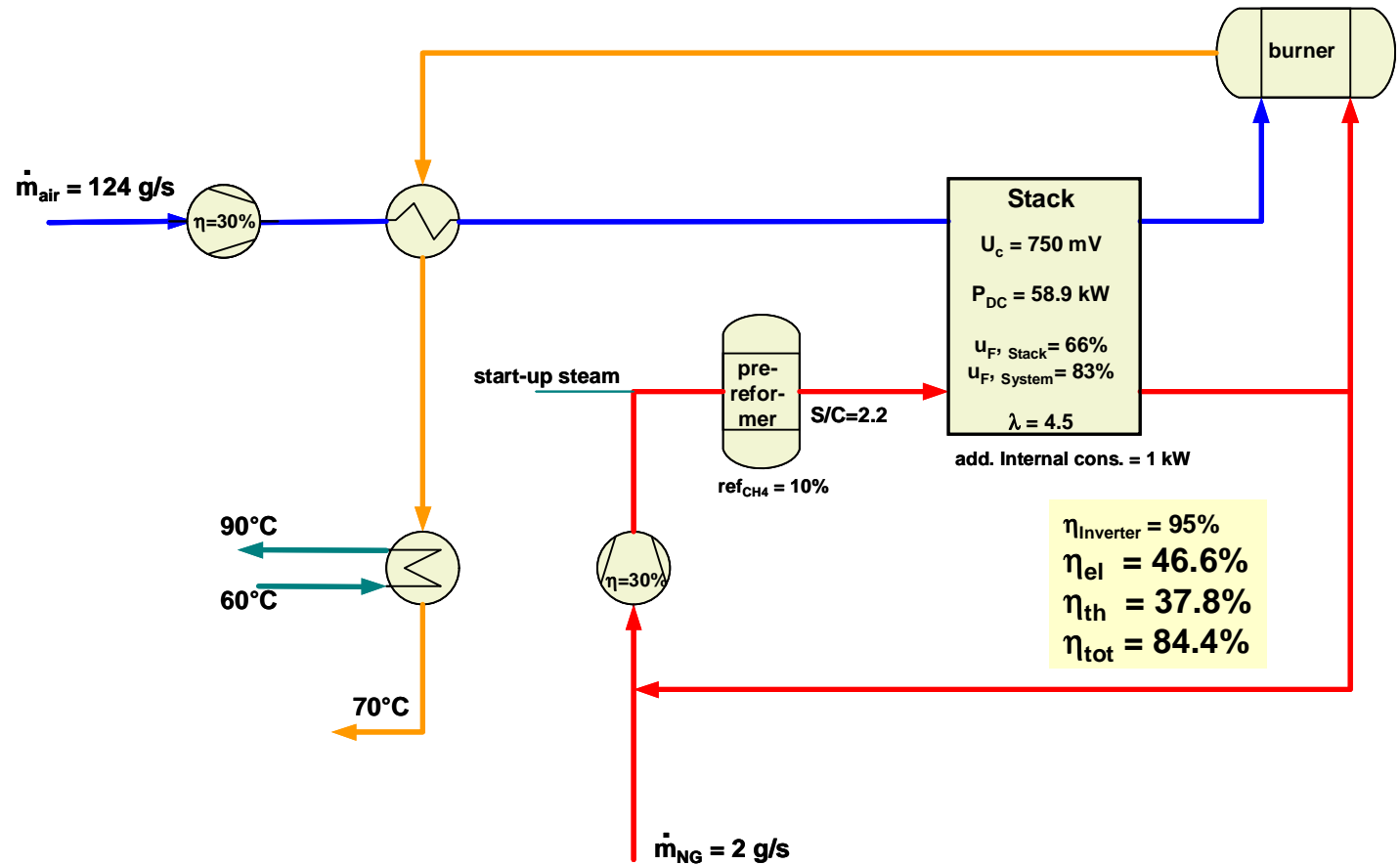
Ø Cost

Ø Availability



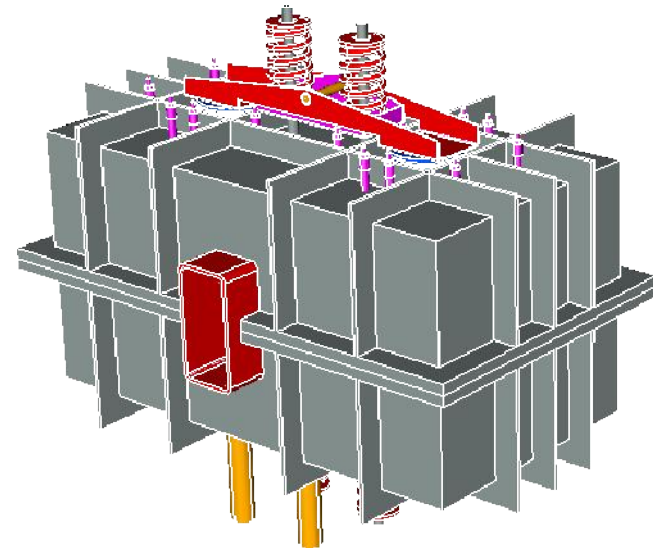
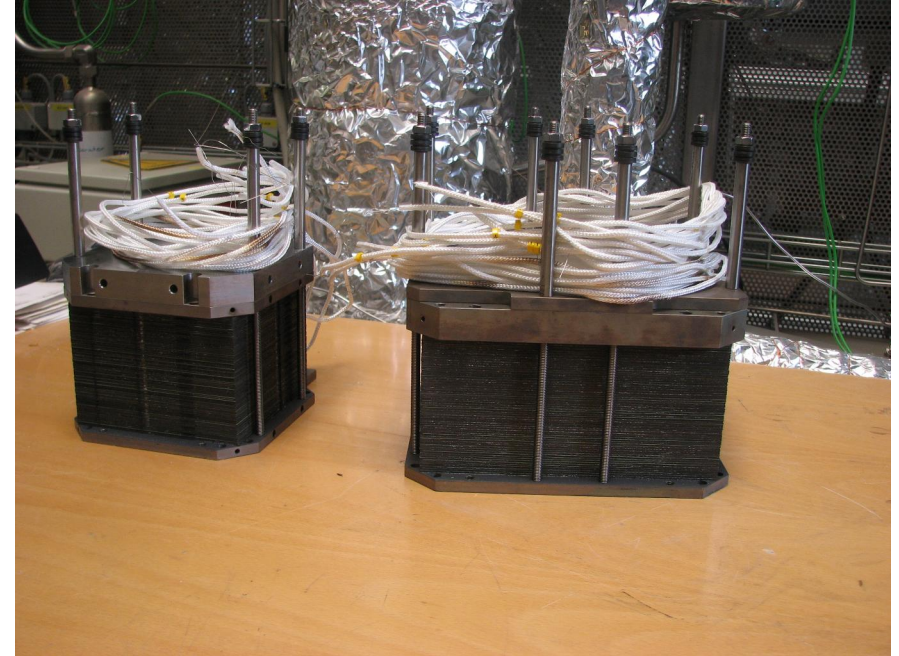
System analysis of 50 kW unit

- ∅ Three concepts with different anode recycle have been analysed.
- ∅ Catalytic burner and thermal burner.
- ∅ Different air heating and pre-reformer heating regimes.
- ∅ Very small differences in electrical efficiency found
- ∅ Next step different cell voltages and compressor efficiencies used.
- ∅ System net efficiencies between 46% and 56% were found. It was also noted that auto thermal reforming results in low efficiency: 29%.



Stack development and integration

- Ø 18*18 cm cells
- Ø 60 cell stack
- Ø Co- or counter flow
- Ø Nominal output 2.5 kW
- Ø 24 stacks gives 50 kW net for system
- Ø A four stack module has been developed

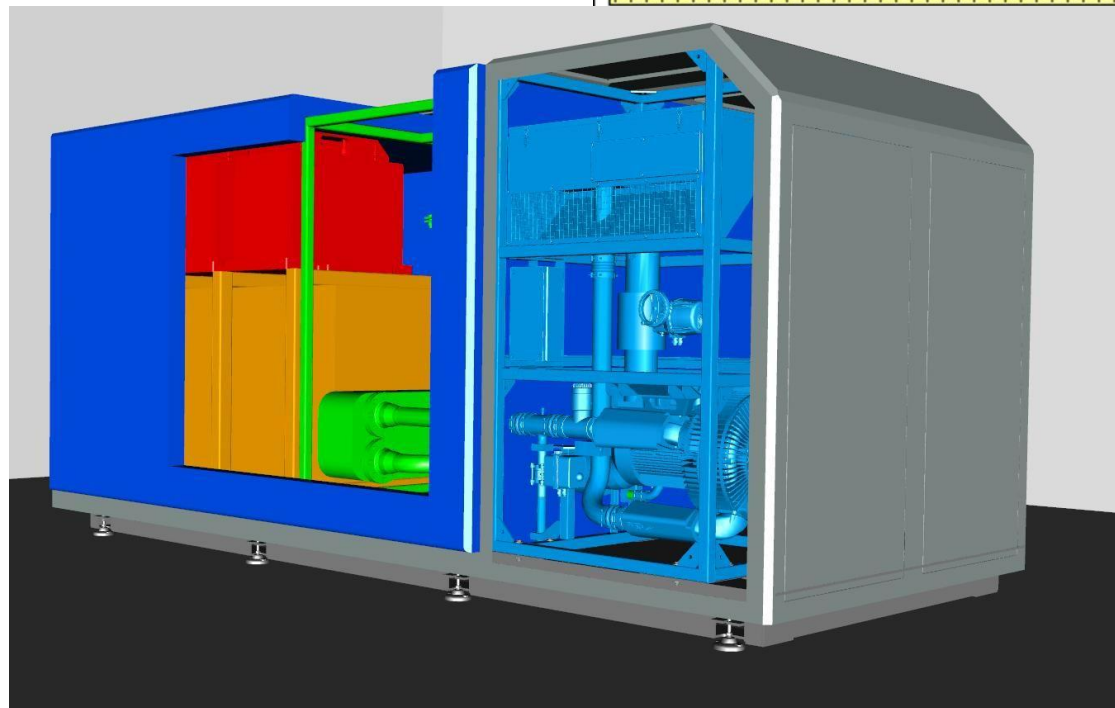
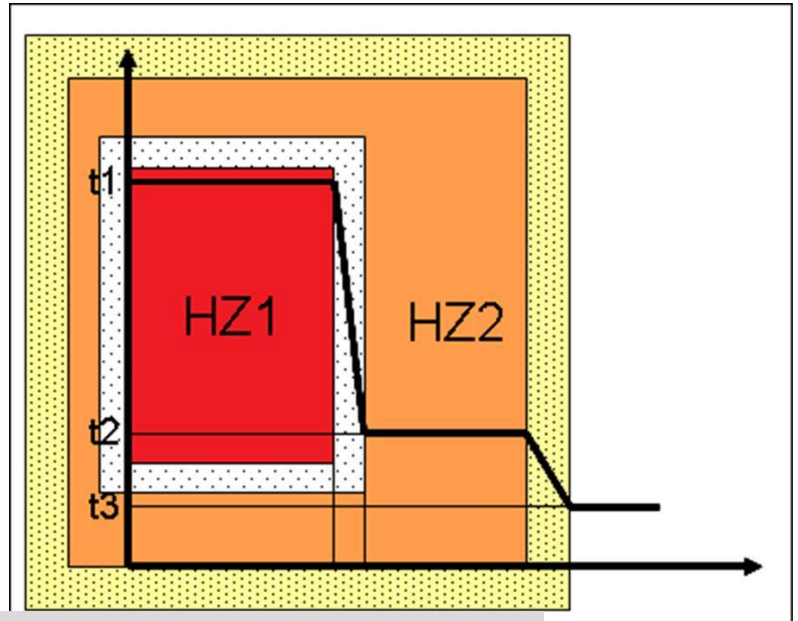


System design

Improved concepts:

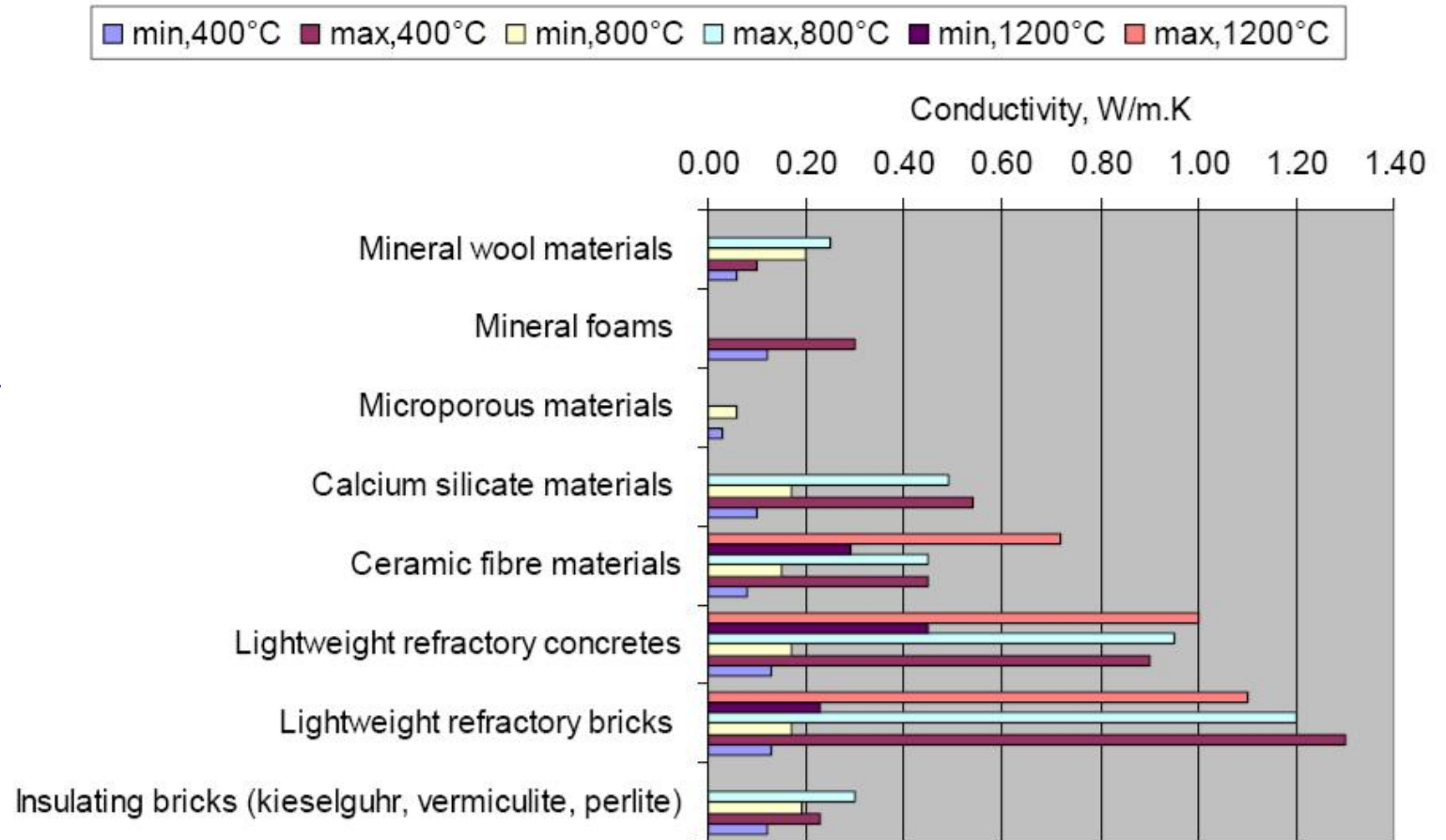
Ø Heat zone optimisation

Ø System, sub-system and component integration



Insulation

- Ø Insulation materials properties have been studied
- Ø Low thermal conductivity resulting in thinner insulations
- Ø Less volume

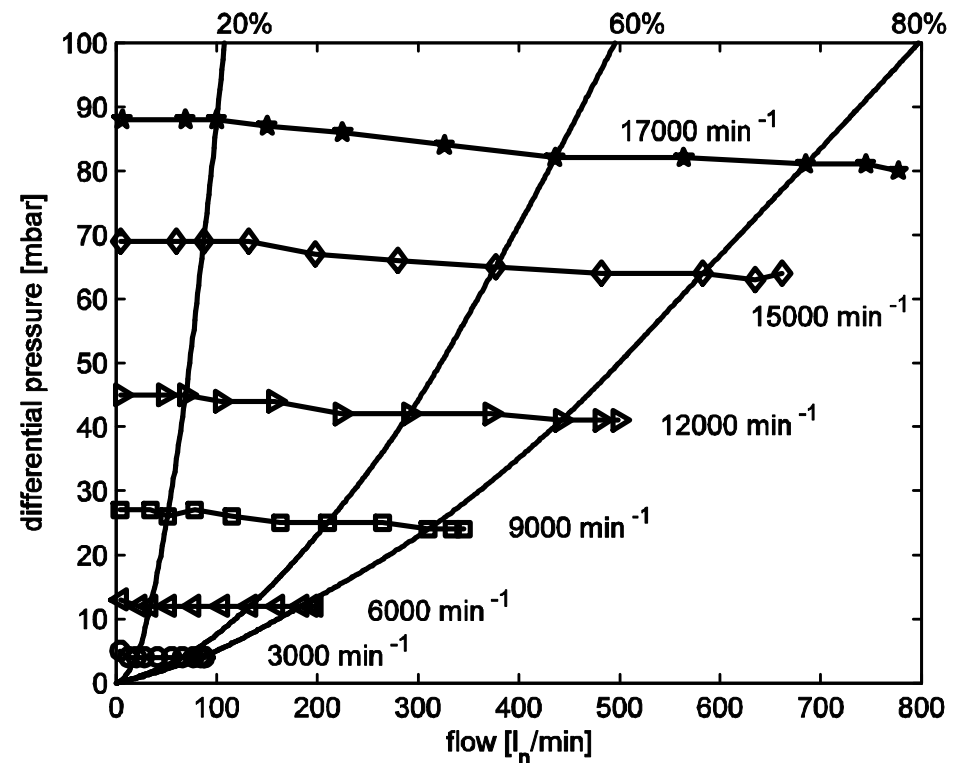


Air blowers and anode recirculation blowers for non-pressurised systems

A centrifugal compressor was developed and tested

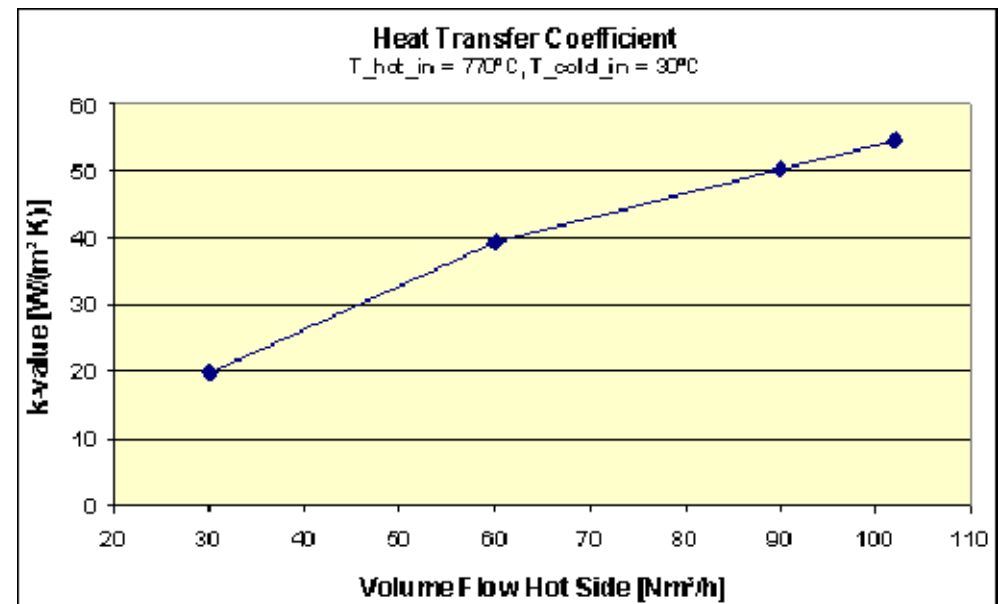
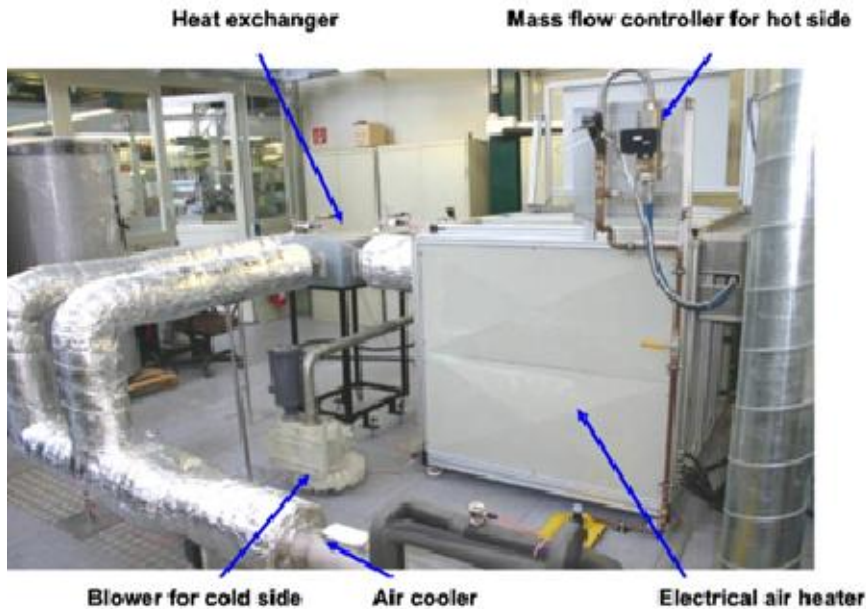
Ø Automotive supercharger with new design electric motor was developed and tested.

- Ø Anode recirculation blower must stand heat (300 °C)
- Ø One existing unit has been tested



Heat exchangers.

- Ø Wärtsilä has studied manufacturing, performance and cost of different heat exchangers
- Ø Test device have been constructed
- Ø Heat exchangers will be purchased and tested
- Ø FZJ has constructed new test bench for heat exchanger testing

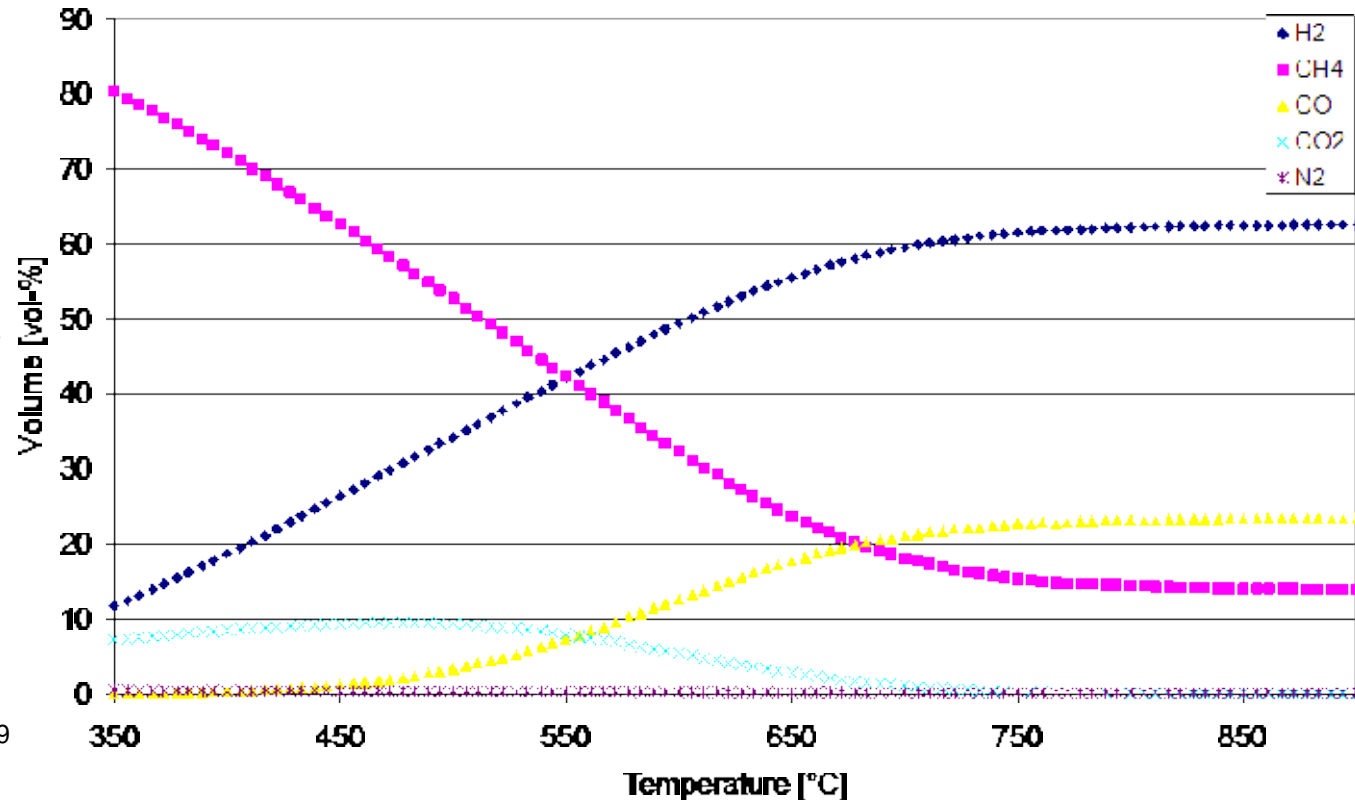


Fuel processing equipment

- Ø Analysis of fuel processing options in regard to performance and cost
- Ø An integrated steam reformer including heat exchangers, electrical heater and reformer was designed

Ø Thermodynamical calculations on recycle fractions performed

On Feed dry



Power electronics

Analysis of requirements

∅ Controllability and sensitivity to stack variation

∅ Isolation requirements

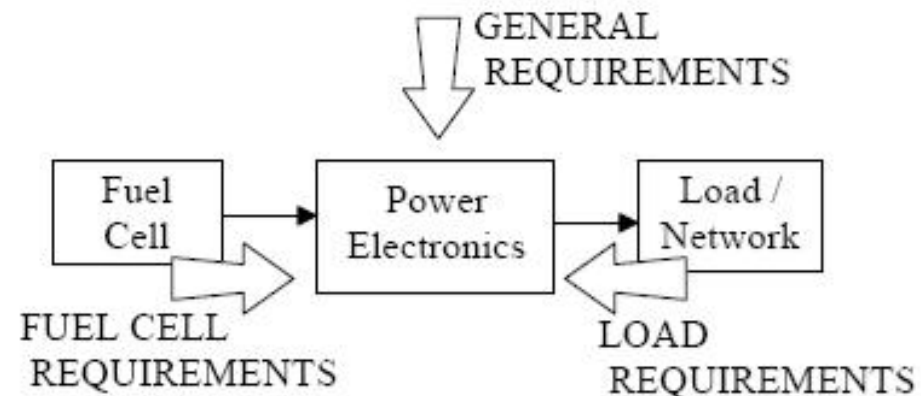
∅ Cabling arrangement and losses

∅ Power conversion arrangement and complexity

∅ Stack monitoring and protection arrangements

∅ A test rig was constructed (Wärtsilä)

∅ A prototype concept for power electronics has been designed



Concept verification

The objective is to verify the concepts for system and sub-systems developed in this project and related projects. The concepts are

Ø50 kW SOFC atmospheric CHP plant

ØComponents for 50 kW SOFC have been verified; blowers, heat exchangers and reformers



Supporting activities

The objectives are to ensure that the most relevant issues of using a SOFC power plant are clarified

Ø Fuel quality requirements, gas cleaning, fuel processing options

- Focus on biofuels
- Influence of toluene, HCN and HCl on cells

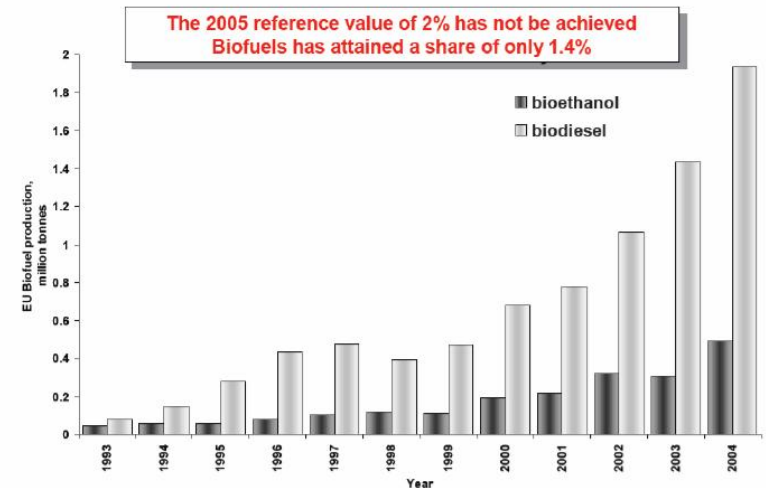
Ø Grid connection rules and standards in Finland, UK, other EU

- Focus on islanding issues and requirements of isolating transformer

Ø Safety and standards

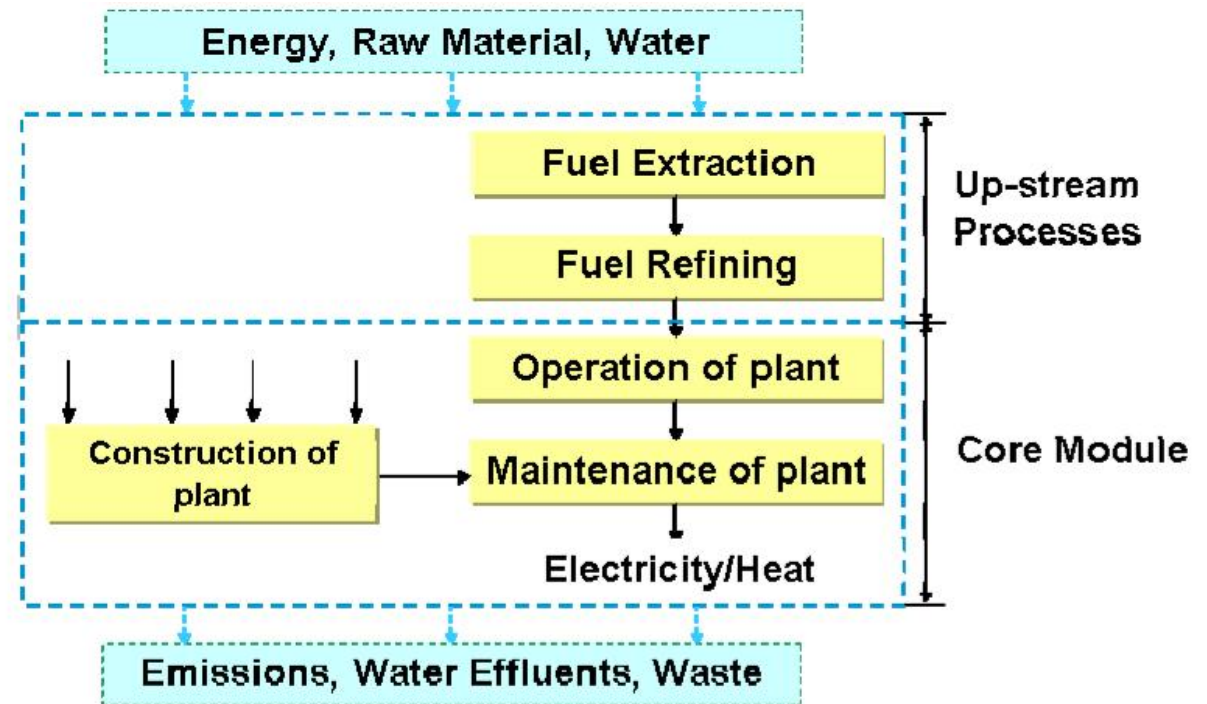
- Safety requirements, legal regulations and standardisation

Biofuels in the EU-15



Life cycle analysis

- ∅ Comparison of 50 kW non-pressurised with pressurised and other power plants
- ∅ Including different fuels
- ∅ Starting from raw materials to operation and recycling when dismantled



The preliminary results shows an clear advantage for SOFC compared with Conventional natural gas power plant



Training and dissemination

- Ø Technology workshops
 - Ø Internal workshops
 - Ø Two public workshops on BoP and system issues

- Ø Summer schools
 - Ø Two summer schools as a continuation of those organised by Real-SOFC



*Introduction to Solid Oxide Fuel Cell Science and Technology
Chania, Crete 2008*





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Thank you for your attention