



SOFC System Development in VTT

Jari Kiviaho, Matias Halinen, Matti Nojonen, Jaakko Saarinen and Rolf Rosenberg
EFC2005 14.12.2005



Contents

- **Background**
- **Networking**
- **Project structure**
- **Reforming**
- **Cell and stack testing**
- **5 kW demonstration and BoP**
- **Modelling**
- **Conclusions**

Background

- ✓ Energy production is facing new challenges in the coming years. The main problems are:
 - ✓ The threat for climate change
 - ✓ The rising energy cost
 - ✓ The decreasing self sufficiency in energy resources
- ✓ Therefore energy technologies with new fuels and higher efficiencies are needed
 - ✓ Combined power and heat
 - ✓ Higher electrical efficiency
 - ✓ Multi fuel use
- ✓ SOFC power plants fulfil these
 - ✓ Electrical efficiencies up till 60% are promised
 - ✓ CHP efficiencies up to 90% are promised
 - ✓ All hydrocarbon fuels are possible with simple fuel processing, CH₄, CO and H₂ direct

FINSOFC project objectives and organization

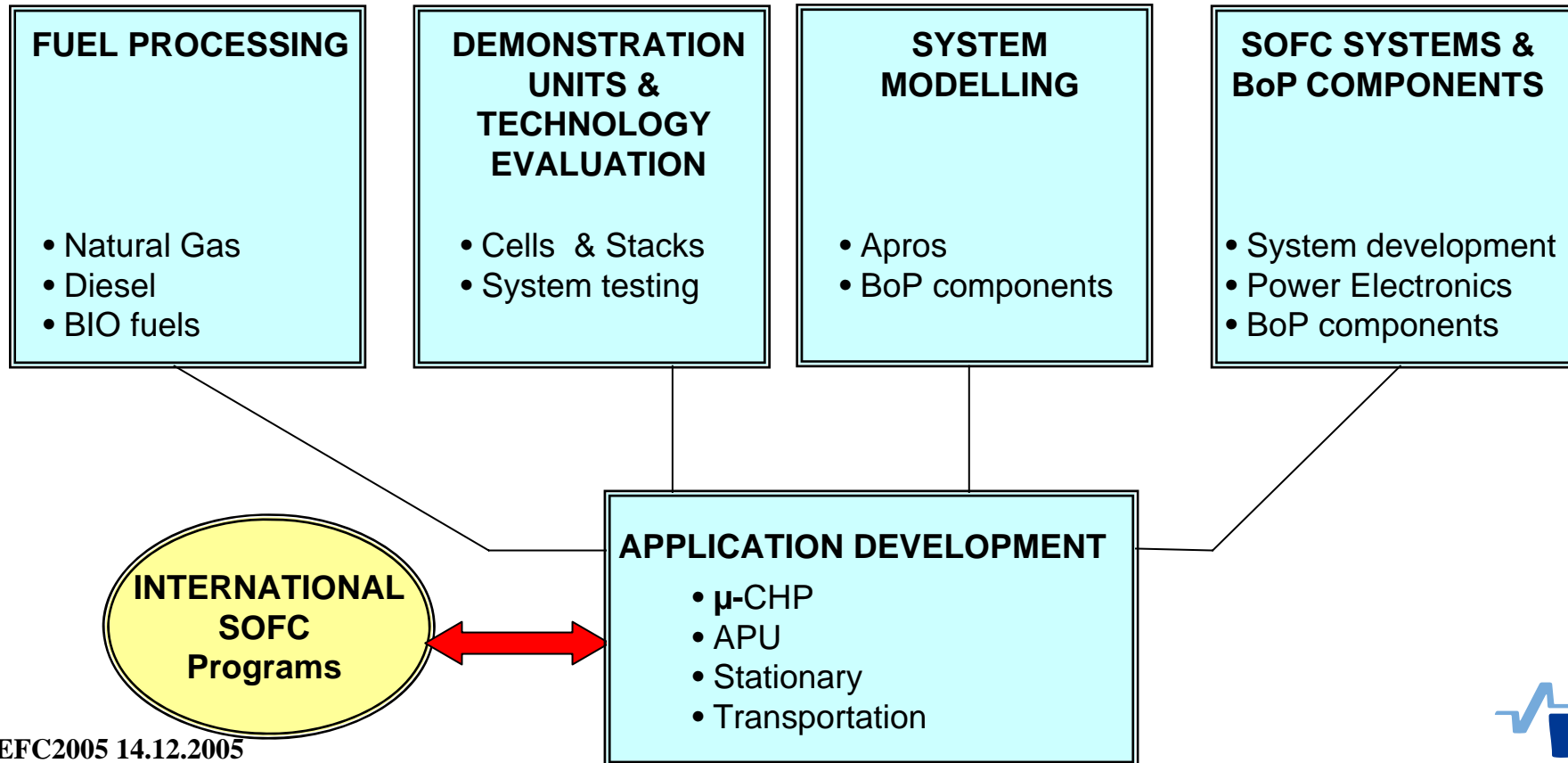
- ✓ **The FINSOFC project is the basis for a national SOFC research and technology program.**
- ✓ **The purpose is to support the industry in its R&D work and encourage the industrial production of SOFC based systems and components.**
- ✓ **The project include technology development, technology transfer, training and dissemination of information on fuel cells.**
- ✓ **The project has been organised as a part of the National Technology Agency of Finland (Tekes) DENSY - Distributed energy systems technology programme.**
- ✓ **The budget is 6 m€ and it is jointly funded by Tekes, VTT and industry.**

Project partnerships

- ✓ The project is co-ordinated by VTT. The project manager is Dr. Jari Kiviaho.
- ✓ The participants are VTT, Helsinki University of Technology, Tampere University of Technology and industry.
- ✓ The industrial participants are Wärtsilä Oyj, Fortum Oyj, Neste Oil Oyj, Patria Vehicles Oy, Verteco Oyj, Gasum Oy, Finnish natural Gas Association, E.ON Finland, Joroisten Energia, Helsingin Energia, Haminan Energia.
- ✓ Energy Research Centre of Netherlands (ECN) and Forschungszentrum Jülich (FZJ) are giving input to the project.

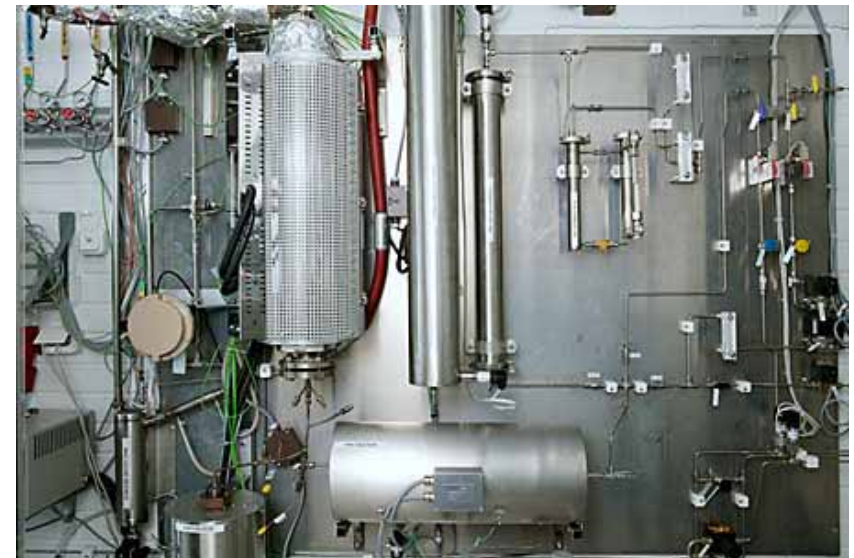
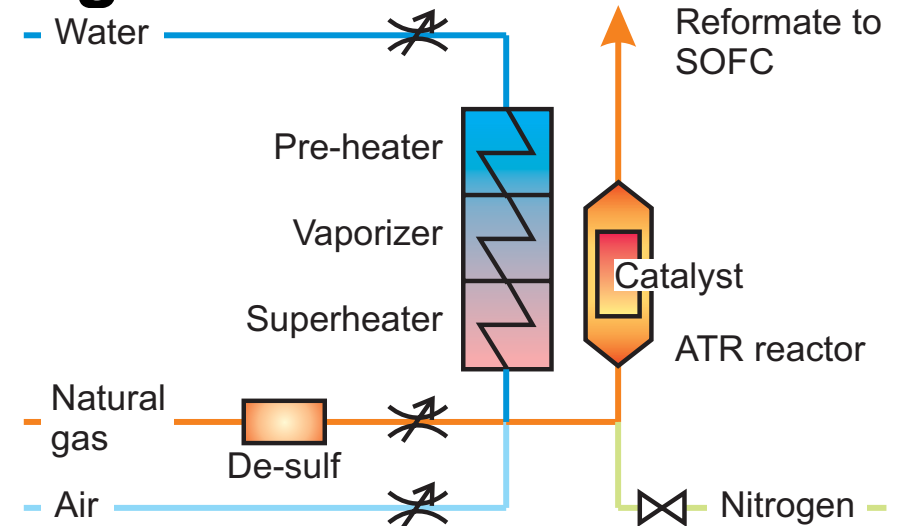
Project structure

- ✓ The basis of the project is the construction and operation of a 5 kW laboratory demonstration plant and to understand how to control it.
- ✓ The Project is build up from five sub items which cover the essential areas of the SOFC technology and are needed for the successful implementation of the demonstration plant.
- ✓ The development of stack components is initiated in 2006.

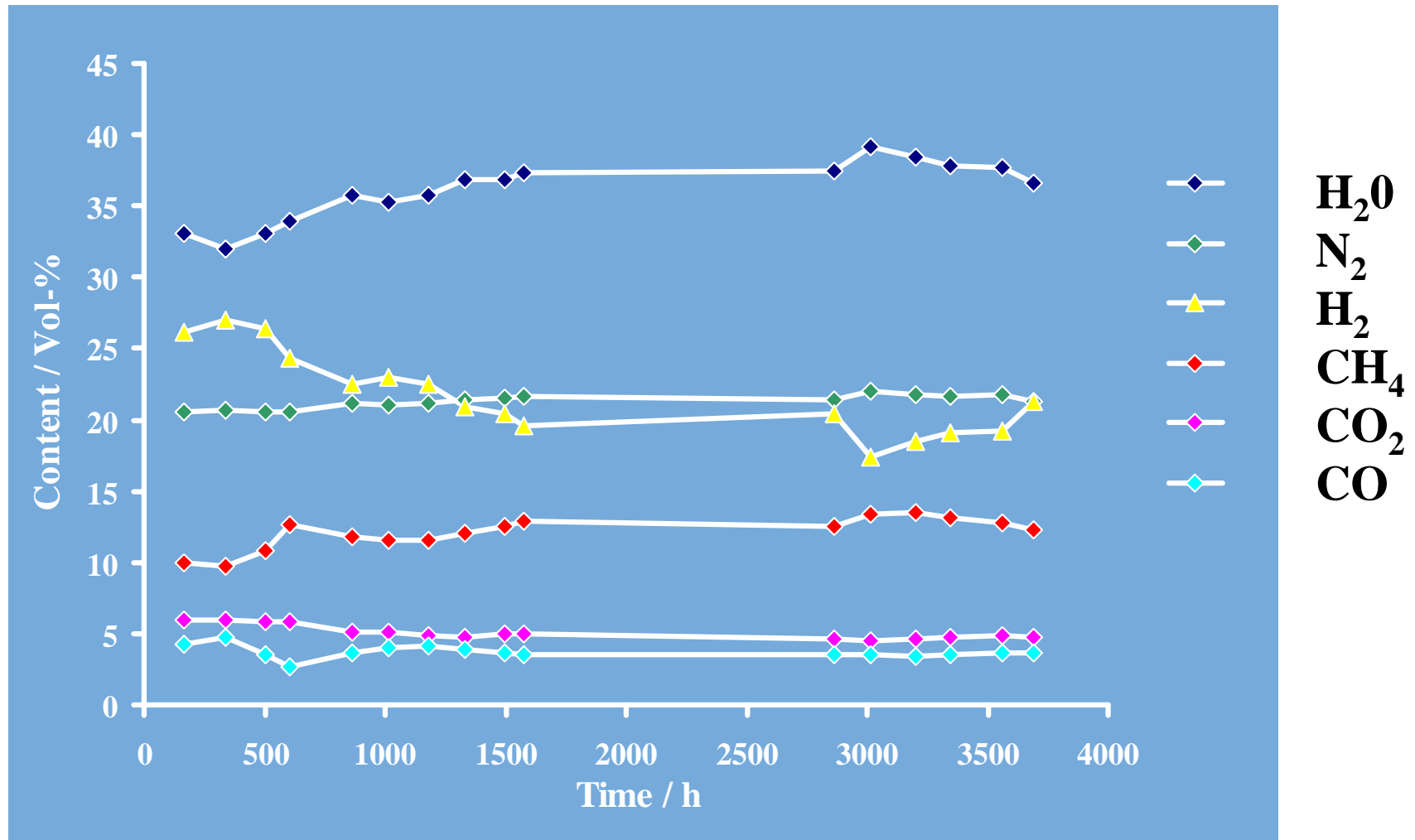


Fuel processing

- ✓ A 1 kW natural gas ATR pre-reformer has been constructed and run for 10,000 h.
- ✓ Sulphur removal by activated carbon, zink oxide and commercial sorbents have been tested (~ 0 ppm)
- ✓ A 15 kW natural gas ATR pre-reformer has been built and run with the 5 kW test unit.
- ✓ H₂: 35%, CH₄: 10%, CO: 5%, CO₂: 5%, H₂O: 20%, N₂: 25%
- ✓ Diesel reforming has been studied in laboratory scale.
- ✓ Next steps: Development of a reformer for low sulphur diesel and biodiesel
- ✓ Gasification of bio mass and gas cleaning are developed in separate projects in VTT.



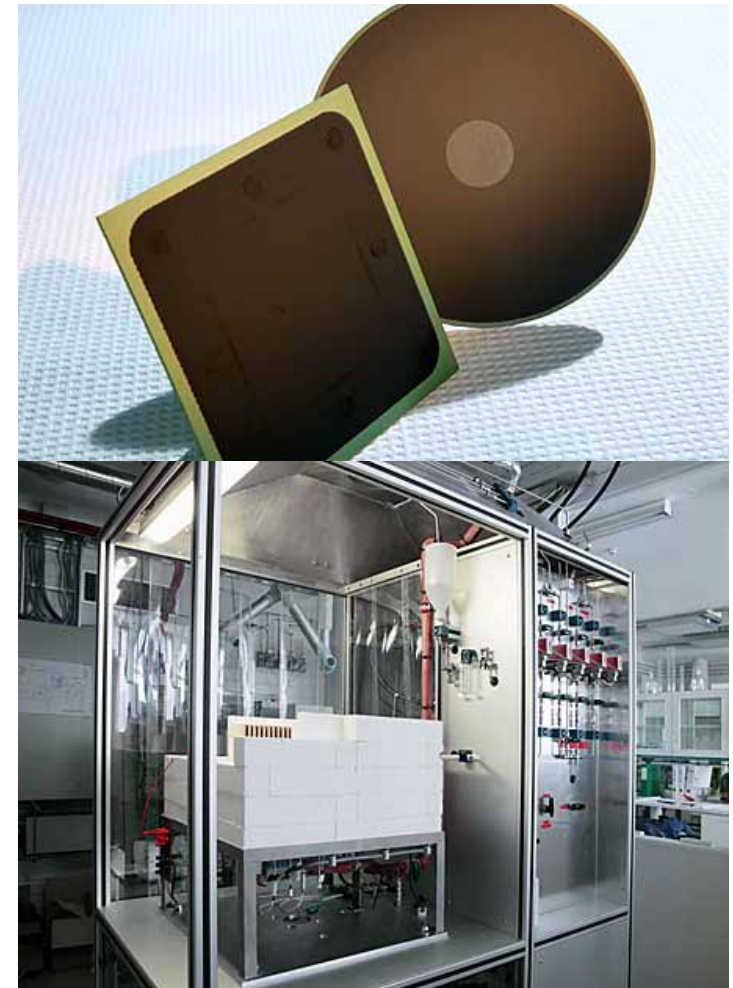
Reformate composition



Cell and stack testing

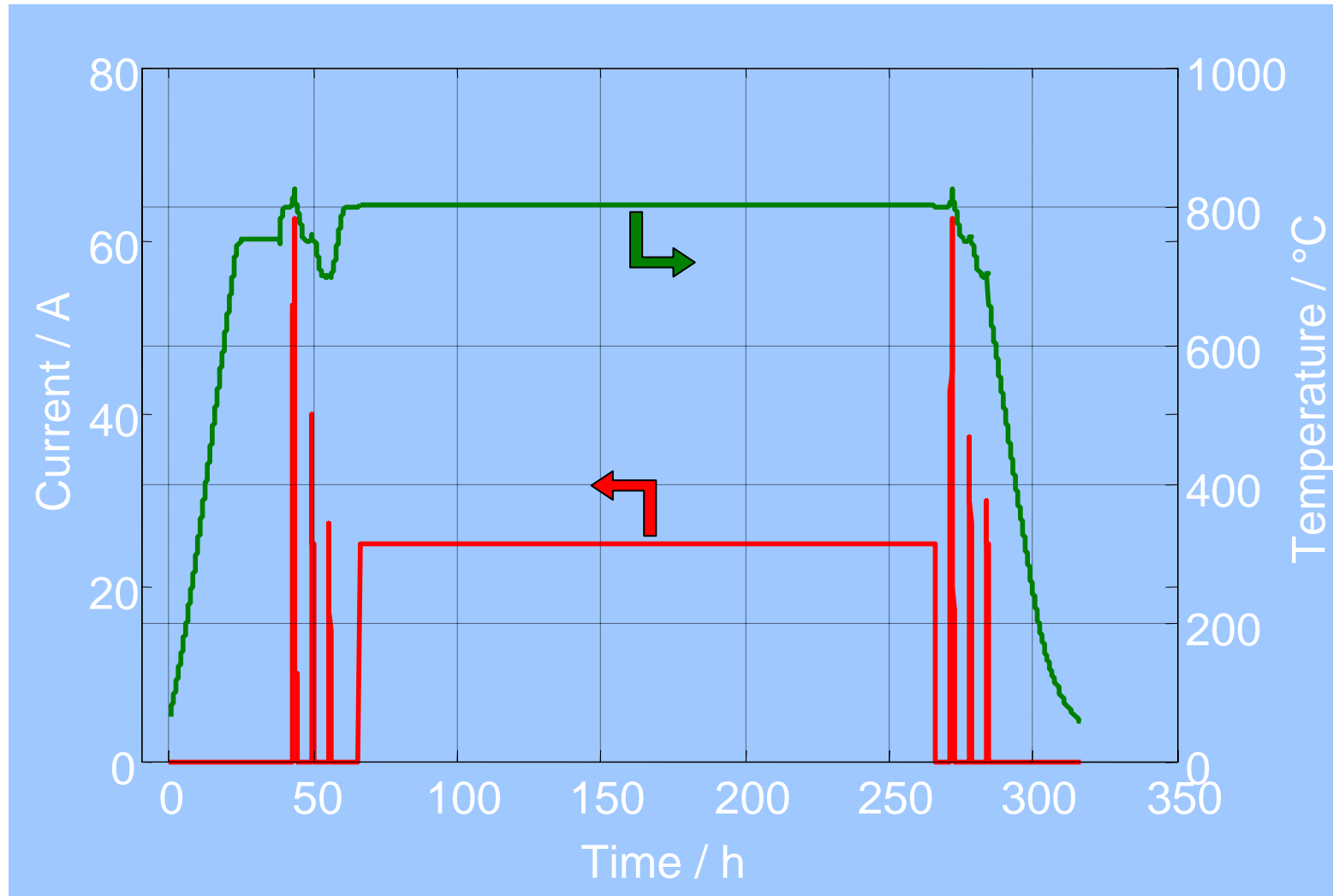
Separate presentation in session 11a

- ✓ Two cell testing systems has been acquired from ECN.
- ✓ These have been completely automated by VTT.
- ✓ One is run on real natural gas reformat, with and without sulphur removal.
- ✓ The other is run with gas from an automatic gas station, which can provide mixtures of H₂, CH₄, CO, CO₂ and N₂.
- ✓ A short stack testing system has been constructed by VTT.
- ✓ It can be run with H₂ and CH₄ and N₂ and mixtures of these.
- ✓ Most of the cell and short stack testing is done within the Real-SOFC project.



Automatic cell testing procedure

Reduction, IV curves in different temperatures, steady state and shut down



5 kW laboratory demonstration

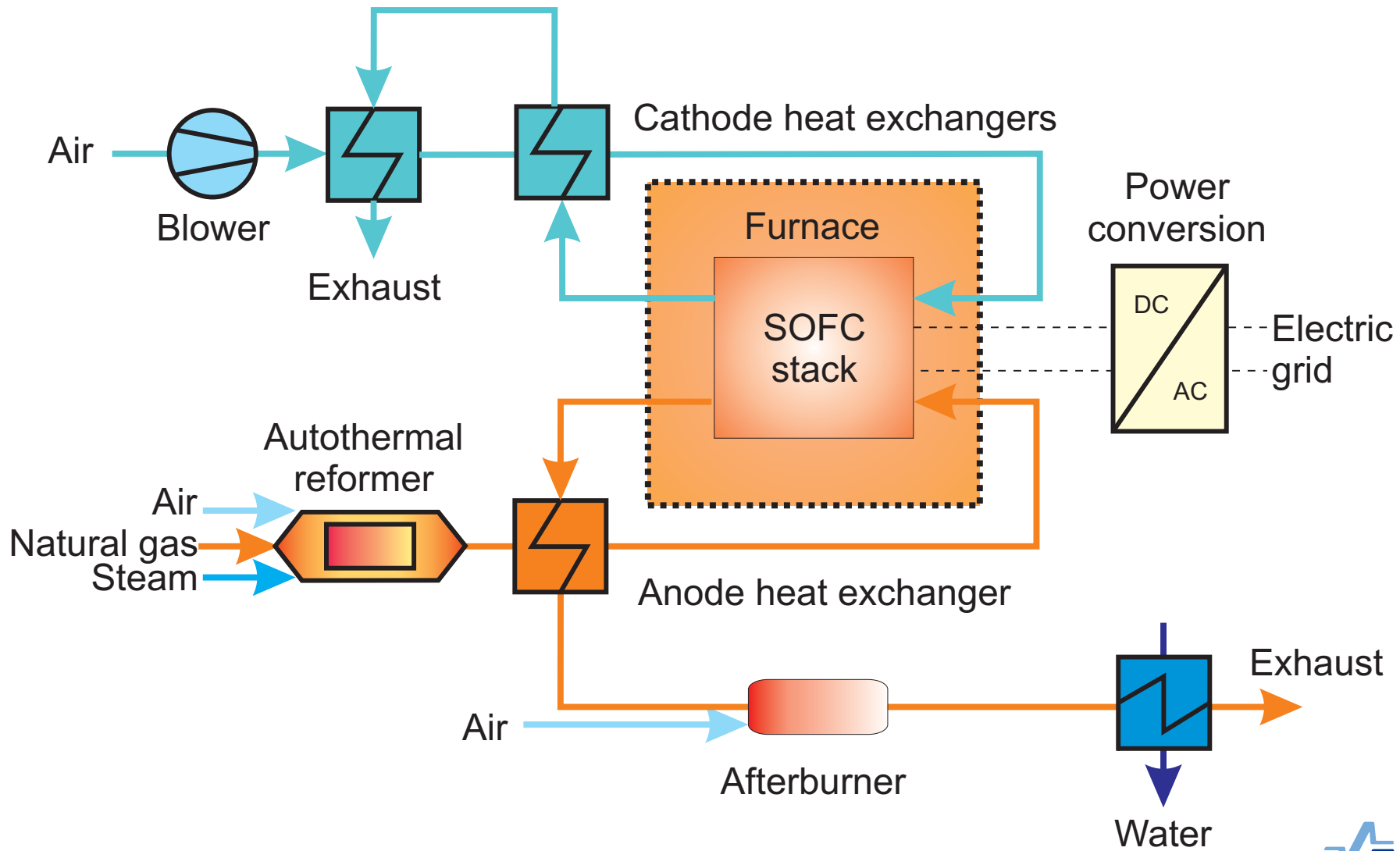
Poster in session 1

A 5 kW SOFC CHP grid connected demonstration system has been constructed and operated for ~3000 hours with 1 kW FZJ stack.

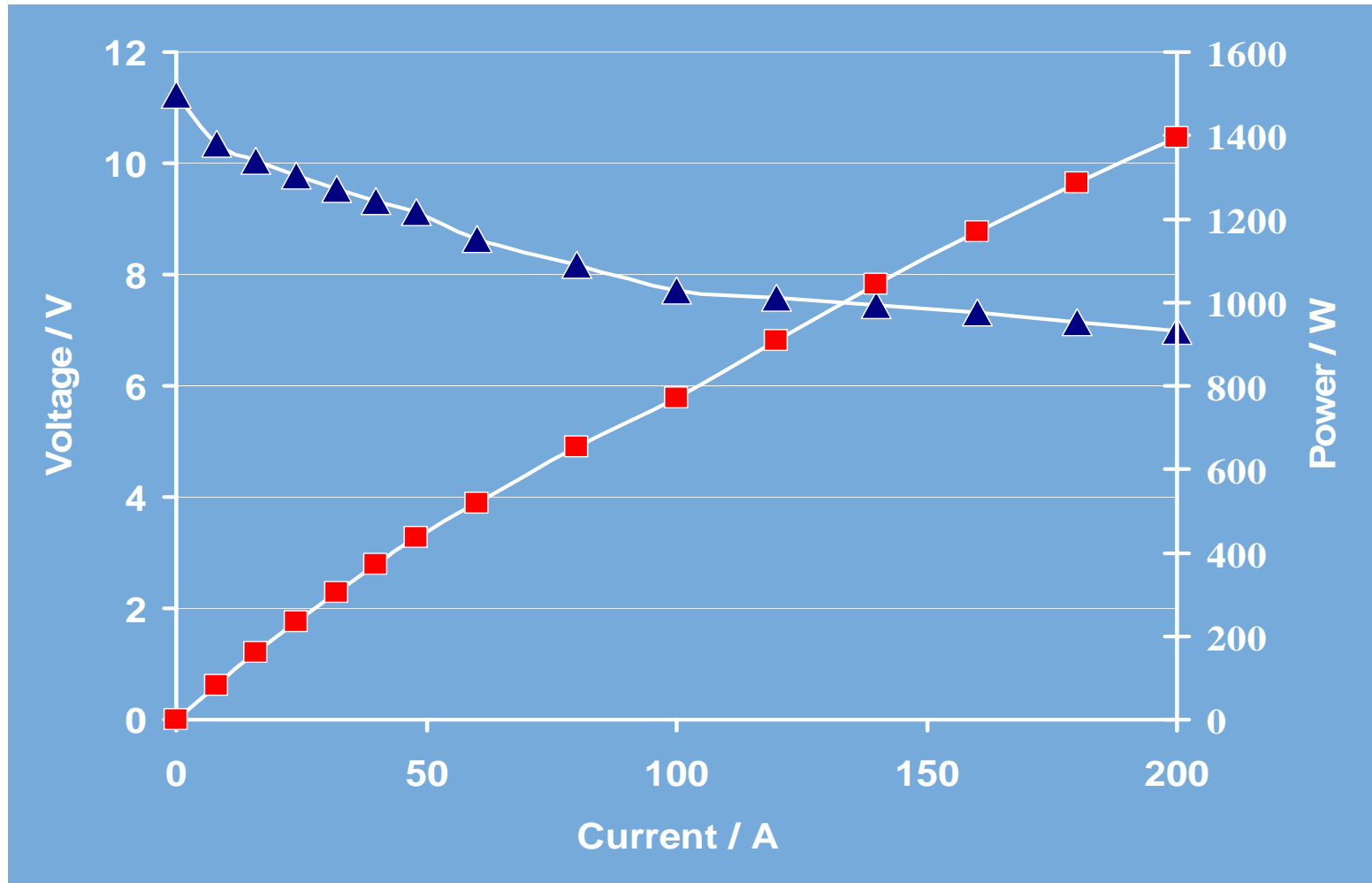
- ✓ NG or hydrogen fuelled
- ✓ Balance of plant:
 - ✓ heat exchangers
 - ✓ power conditioning
 - ✓ control and automation system
 - ✓ reformer (ATR)
 - ✓ many commercial components



5 kW laboratory demonstration



1 kW stack from FZJ



System component development

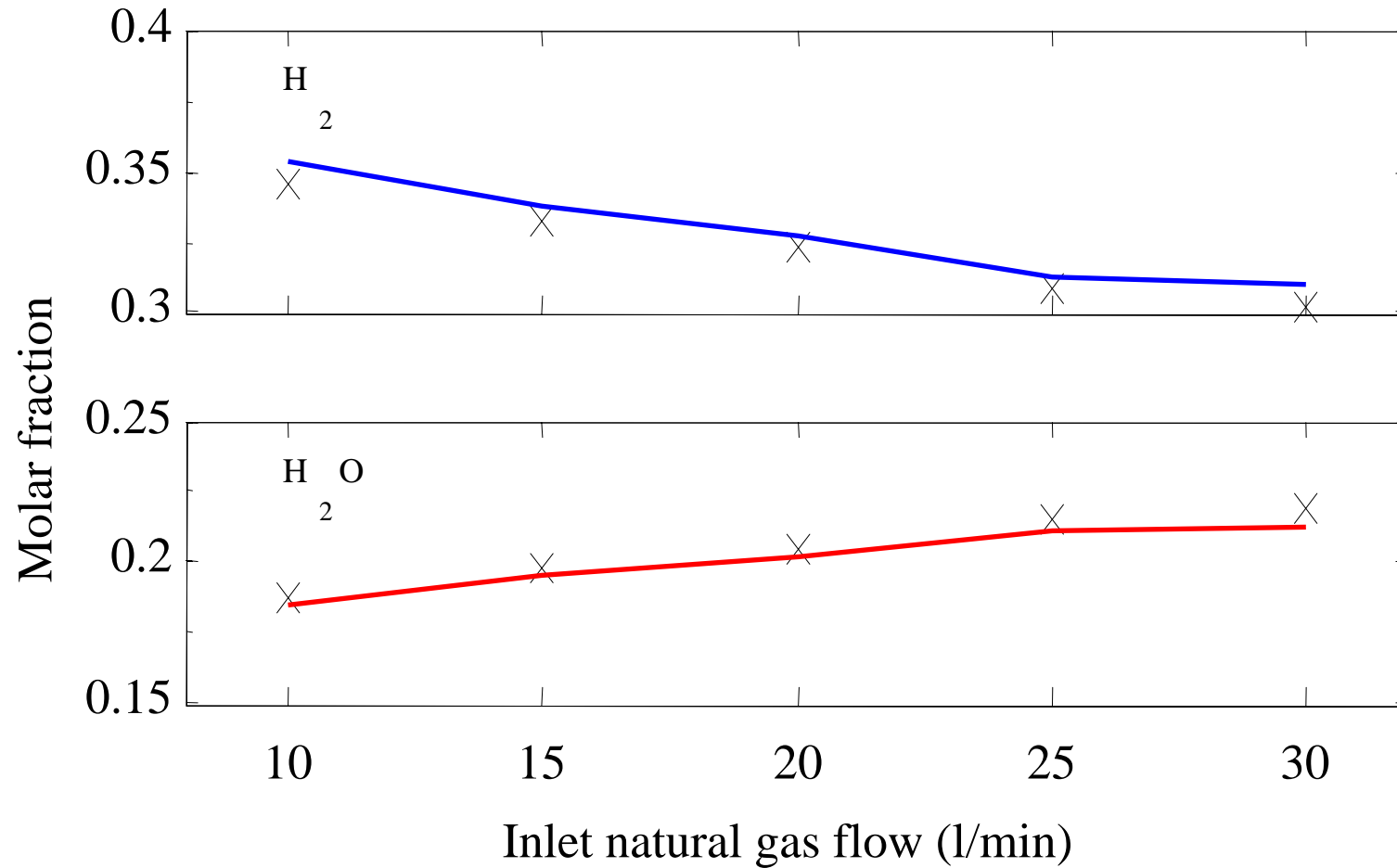
- ✓ **System automation has been developed**
- ✓ **New power electronics developed by Verteco and MSC electronics**
- ✓ **New type of heat exchanger developed by Raucel Oy and VTT.**
- ✓ **New after burner has been developed by VTT and tested**
- ✓ **New 15 kW reformer for natural gas has been developed by VTT and tested for a few thousand hours.**

System modelling

Poster in session 1

- ✓ The objective is to develop a dynamic simulation platform for
 - ✓ identification and evaluation of optimal alternatives for the SOFC system layout and
 - ✓ development of control strategies.
- ✓ It is based on the Advanced process simulation environment (APROS) which is developed by VTT and Fortum.
- ✓ The 5 kW SOFC system model is based on the real test rig and comprises the following main components of the real test system:
 - ✓ The autothermal reforming unit
 - ✓ SOFC stack situated inside a furnace
 - ✓ Catalytic afterburner
 - ✓ Three heat exchangers.
- ✓ The obtained, partially verified, model has been used for the phenomenological studies of the full system during current-voltage measurements of the stack using a simplified and fast 0D-model including internal reforming for the SOFC stack.
- ✓ A 1D stack model has been obtained from FZJ.

Reformer modelling compared with measurements x measurement points



Conclusions

- Starting from zero in 2002 the Finnish SOFC program has managed to build up considerable resources in the form of people, experimental facilities and modelling tools.
- The networking, especially on the national and European levels has been extensive, enabling the joint utilisation of a large base of information and expertise in joint tasks.
- By making the right choices this has been accomplished by moderate funding.
- At present VTT is in a position to participate in joint European projects on an equal basis offering its own expertise as exchange for technology.
- VTT is also ready to support the industry in its research and development work and support universities in educating new researchers for fuel cell related tasks both in industry and research organisations.

Project participants

- ✓ Dr Jari Kiviaho (VTT)
- ✓ Dr. Rolf Rosenberg (VTT)
- ✓ Dr. Matti Noponen (VTT)
- ✓ Mr Matias Halinen (VTT)
- ✓ Mr Jaakko Saarinen (VTT)
- ✓ Mr Kari Koskela (VTT)
- ✓ Mr Jarmo Kleemola (VTT)
- ✓ Dr. Pekka Simell (VTT)
- ✓ Mrs M-L Koskinen-Soivi (VTT)
- ✓ Mr Jouko Kukkonen (VTT)
- ✓ Mr Pekka Saari (VTT)
- ✓ Mr Eero Leppämäki (VTT)
- ✓ Ms Sanni Mustala (VTT)
- ✓ Mr. Jukka Ylijoki, VTT
 - ✓ Mr. Markku Hänninen, VTT
 - ✓ Dr. Olli Tiihonen, VTT
 - ✓ Mr Erkko Fontell (Wärtsilä)
- ✓ Mr Miika Jussila (Wärtsilä)
- ✓ Mr Kimmo Keränen (Wärtsilä)
- ✓ Dr. Pauli Jumppanen (Wärtsilä)
- ✓ Prof. Outi Krause (HUT)
- ✓ Mrs Reetta Kaila (HUT)
- ✓ Prof. Kari Saari (HUT)
- ✓ Prof. Aarne Halme (HUT)
- ✓ Mr Reijo Takala (Verteco)
- ✓ Dr Pekka Knuuttila (Fortum)
- ✓ Mr Jorma Stick (Fortum)

ACKNOWLEDGEMENT

- **The financial support from**
 - **Tekes (National Technology Agency of Finland)**
 - **Wärtsilä Oyj**
 - **Fortum Oyj**
 - **Neste Oil Oyj**
 - **Patria Vehicles Oy**
 - **Verteco Oyj**
 - **Gasum Oy**
 - **Finnish natural Gas Association**
 - **E.ON Finland**
 - **Joroisten Energia**
 - **Helsingin Energia**
 - **Haminan Energia**
- **is acknowledged.**