a FCH JU Project

ASTERIX III
256764

ASsessment of SOFC CHP systems build on the TEchnology of htceRamIX 3

January 2011 to December 2012

Per Balslev and Olivier Bucheli
Dantherm Power and HTCeramix
peb@dantherm.com, olivier.bucheli@htceramix.ch

ASTERIX III

Project: **Micro Combined Heat and Power based on SOFC technology**

R&D to achieve proof - of - concept of µCHP fuel cell systems

Budget: **Total: 3096 k€** **Funding: 1361 k€** **2011 – ~~2012~~ 2014**

Partners:

Dantherm Power, DK: Fuel cell system integrator

HTceramix, CH and I: SOFC cell, stack and HoTbox™ producer

EIFER, D: Energy research and relation to large energy company

CNR-ITAE, I: National research center on energy

ASTERIX III

Project achievements

- **The SOFC based µCHP have been simulated as integrated units in single a family house based on data for France, Germany and Denmark with different operational strategies:**
  - Heat following
  - Power following
  - Size of heat storage
  - Integrated with out heat storage
- **SOFC HoTbox development have shown capability to start/stop without forming gas**

ASTERIX III

Gaps/Bottlenecks

- Development of SOFC HoTbox is more challenging than anticipated, i.e. start-up/shut down procedures.
- The preliminary concept of the HoTbox has proven, however with delay (15 months)
- As consequence, the design of HoTbox has also been frozen with delay
- µCHP development is delayed as a consequence

The establishment of µCHP systems specifications takes into account :

- The volume of the water tank
- The technical characteristics of the technology: efficiency, thermal power, response time, possibility of power modulation
- The heat and/or electricity needs (load curves in households or buildings)
- The needs of energy suppliers / control strategies

Name	Value	Unit	∑
FC tot efficiency	90%, 95%	-	2
FC el efficiency	30%, 40%, 50%, 60%	-	4
Maximal el power	0.5, 0.7, 1.0, 1.5, 2.5	kW	4
Tank size	300, 500, 800, (0)	l	3 (4)
Load Curve	France, Germany	-	2
Control strategy	Heat lead, Peak period a/b	-	3

2x4x4=
32 Systems

Π: 576

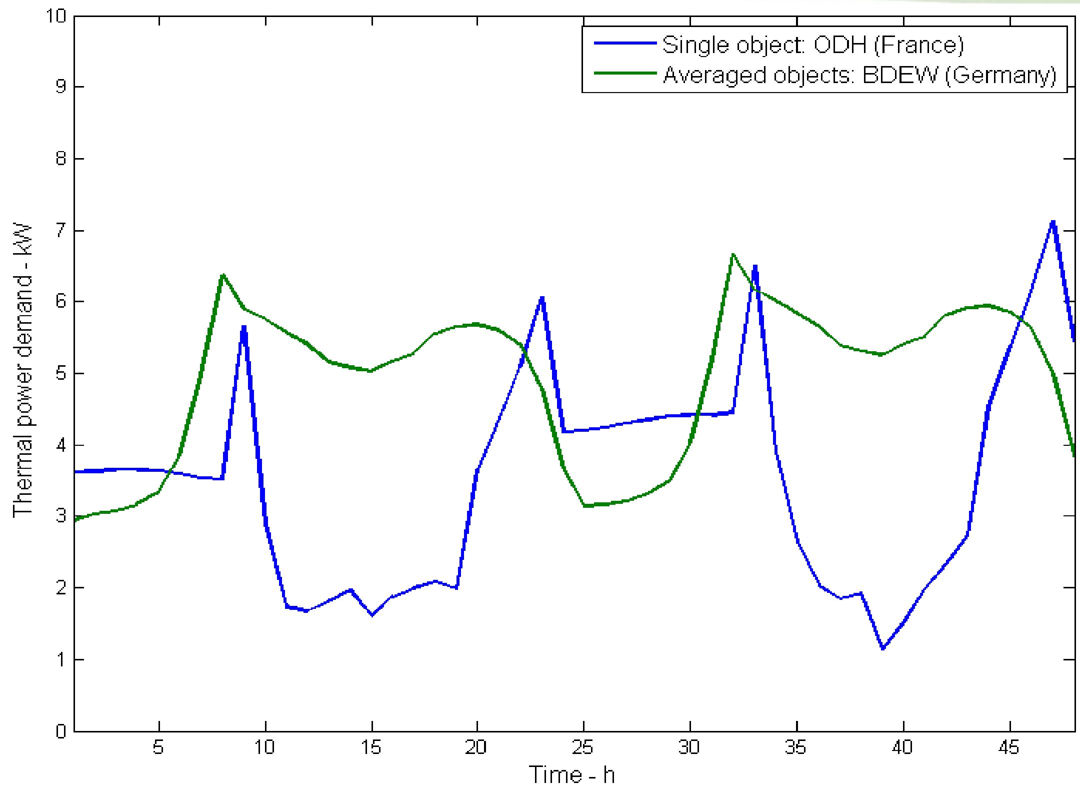
ASTERIX III

Specifications of the µCHP system Methodology
Load curves

German Curve
- Annual thermal demand: 16 MWh
- Flat characteristic (average of several houses)

French
- Annual thermal demand: 24.3 MWh
- Jagged characteristic (behaviour of a single house)

Not necessarily representative for the countries

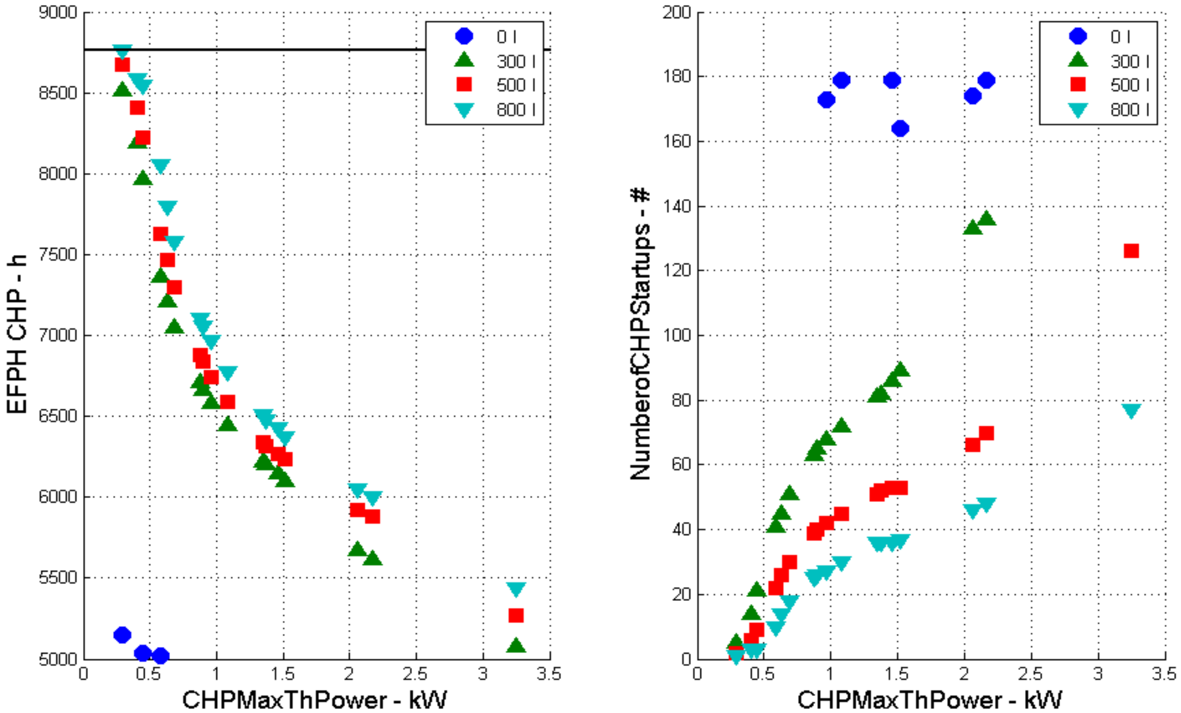


Exemplary 48 hours thermal demand

ASTERIX III

Specifications of the µCHP system
Main results-Influence of parameters

EFPH and NOS over CHP thermal power



Efficiencies:

- Thermal power is the important dimensioning factor
- Low thermal power (– >efficiencies) increase the EFPH and decrease NOS
- Targeted Equivalent FPH, NOS, production share give direct conclusions on Pth

Load curve:

- Smoothness of curve is appreciated for systems with low thermal power
- High demand is appreciated for systems with high thermal power

Overview of Successful Operation preliminary system

Asterix cPox based microCHP systems P_{el} = 0.5 in the field:

- 4 installations done in 2011/2012
- 3 installations in 2012 (Borgo V., Parma and Pergine V.)
- 1 installation in 2013 (S. Michele all'Adige)

Overview of Successful Operation

Field Test Summary

- Operation > 7000h
- Average cogeneration gross efficiency (LHV, DC): 88%
- Max water storage T: 60° C
- Integration of thermal solar panels
- T HB = 740 – 750° C
- $\lambda_{cathode}$ air in the range 4 – 4.7 (depending on HB conditions)

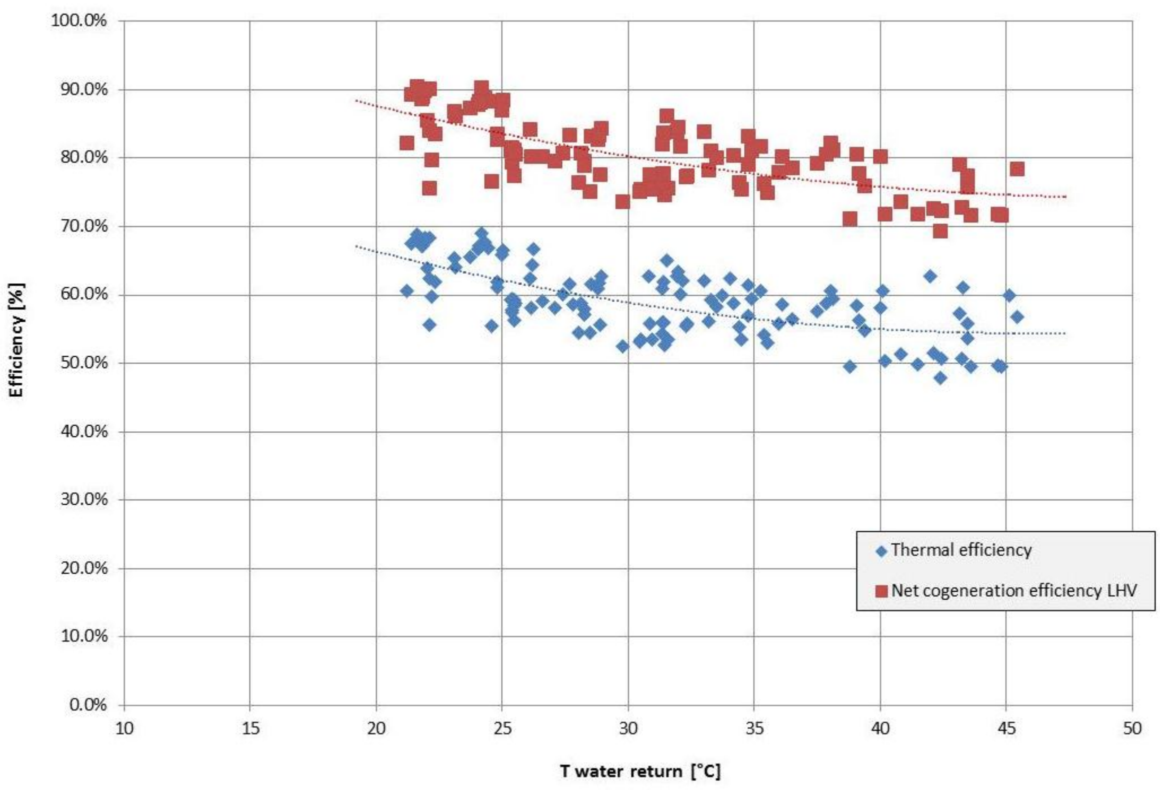
Overview of Successful Operation

Pictures of the Installation at Roncenio Terme (Italy)

3 Asterix $0.5kW_{el}$ in parallel, 500L heat storadge

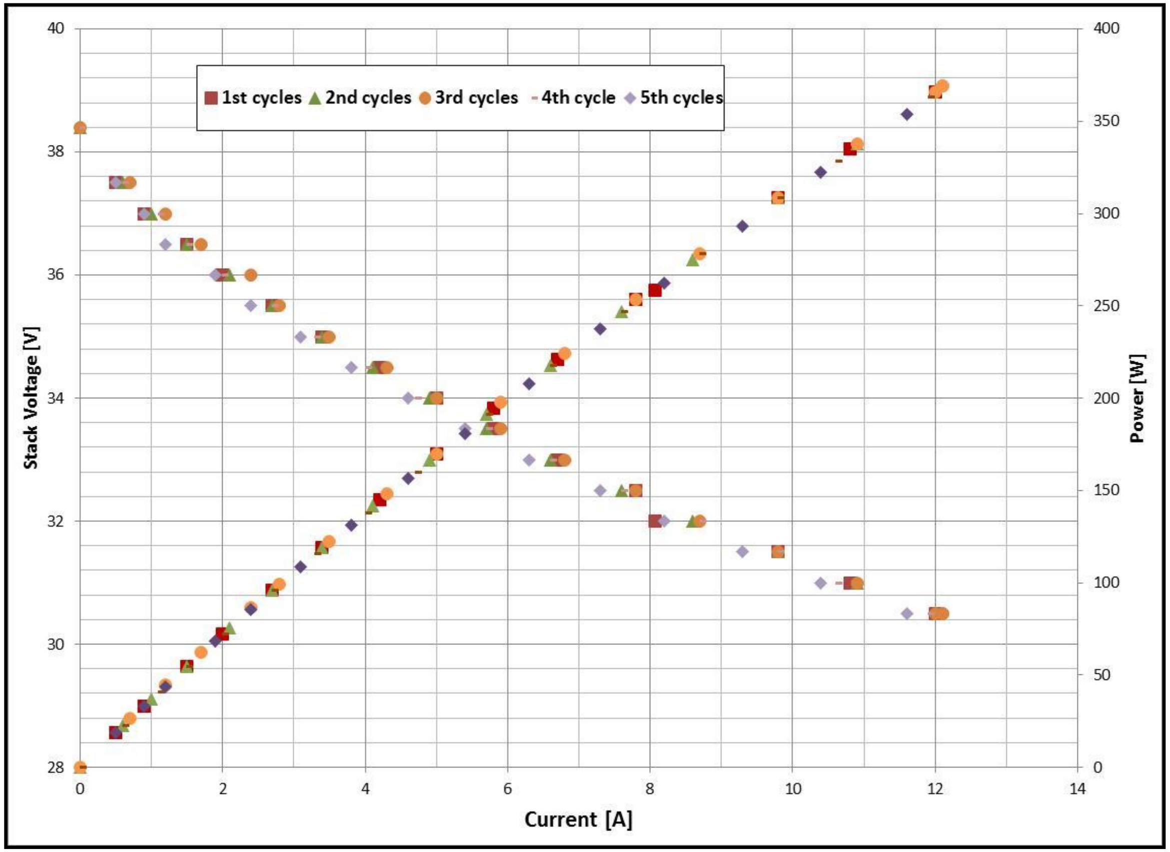
Overview of Successful Operation

HTceramix



Gross and thermal efficiency dependent on water return temperature

Cycling without protective gas



- start-up/shut-down without protective gas
- I-U + I-P curves over 5 cycles

Results Achieved

HTceramix

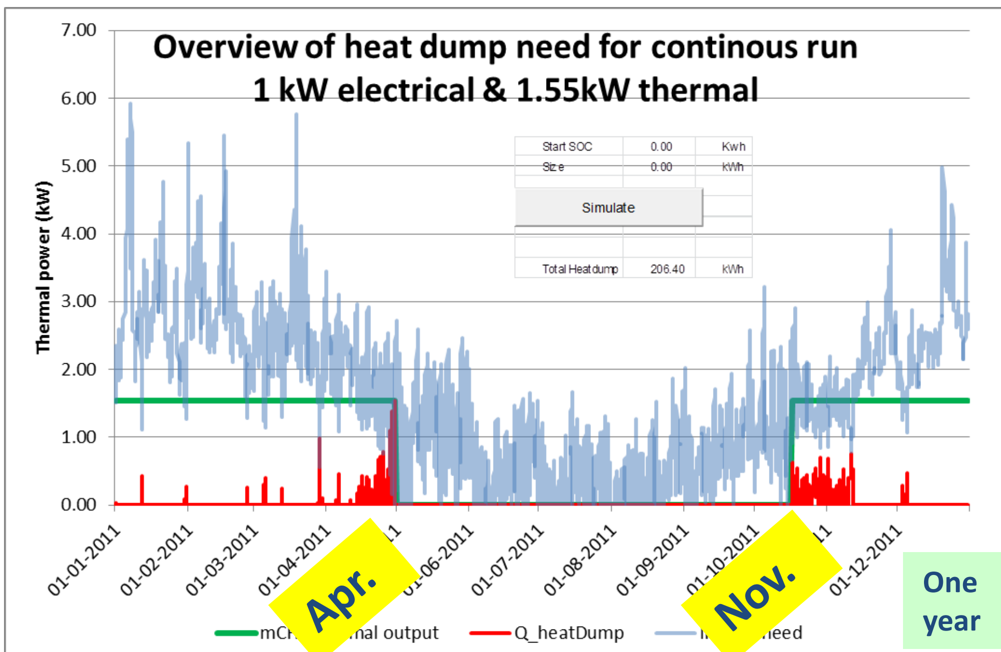
- **cPox pre-reforming simple and robust for micro-CHP**
- **cPox can comply with simple start-up/shut down**
- **SOFC-CPOx system with P < 1.5kW favorable for older houses with average heat demand**

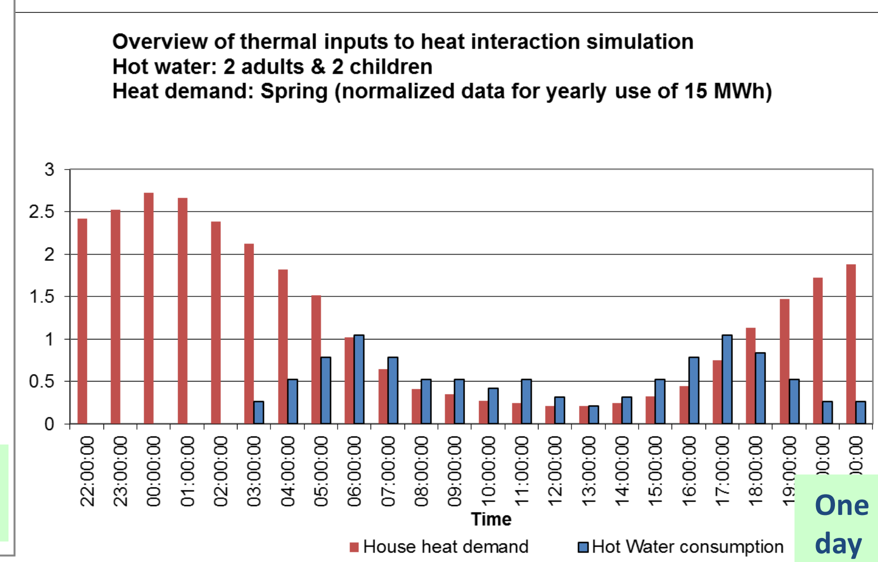
ASTERIX III

Design and develop SOFC µCHP

Verification by test

Simulation of consequence of operating without heat storage



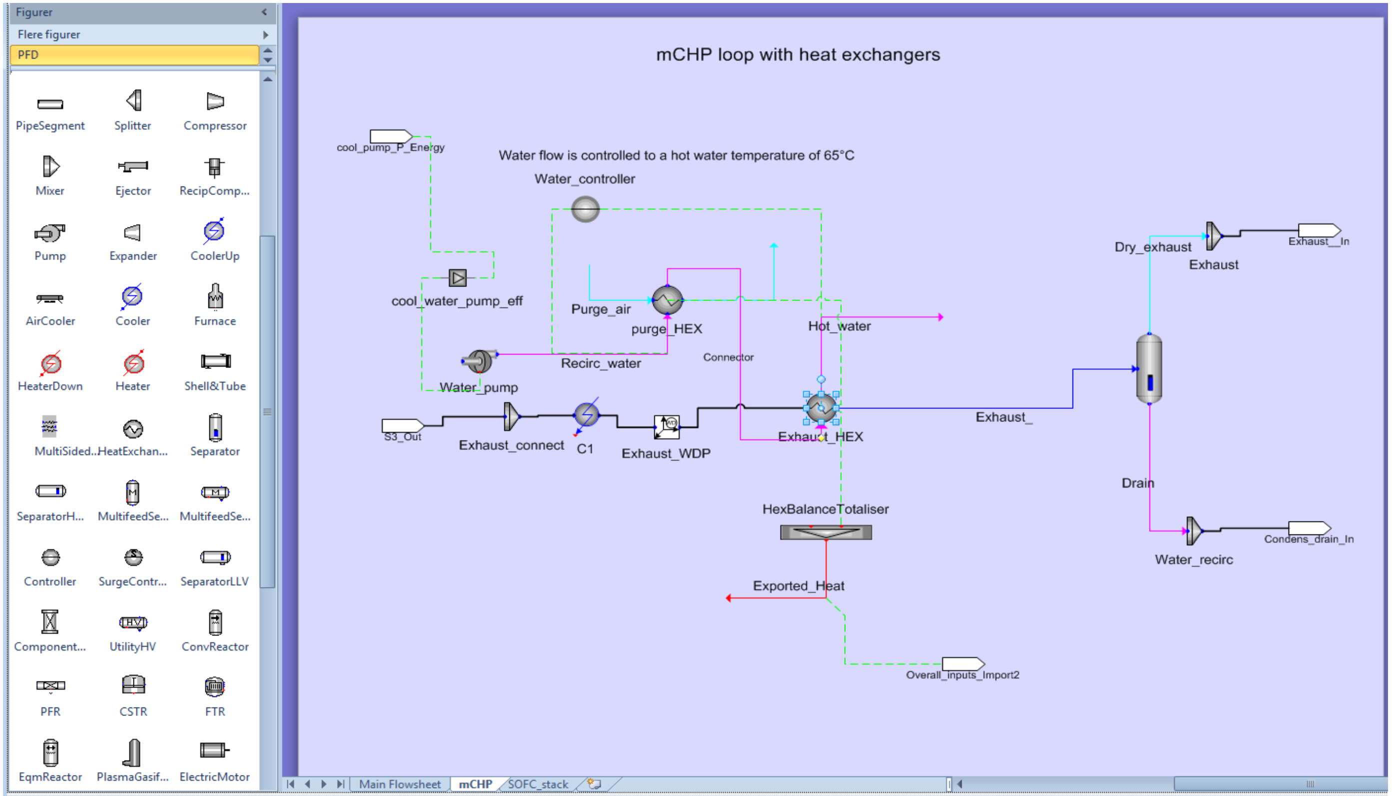


ASTERIX III

Design and develop SOFC µCHP

The developed SOFC system model is written with the software package VirtualMaterials and is basically a thermodynamic library and mathematically solver. The result is a dynamic tool where Microsoft Visio is the component selector with a wide range of build in components that are fast to change and resize (Actual input data needed).

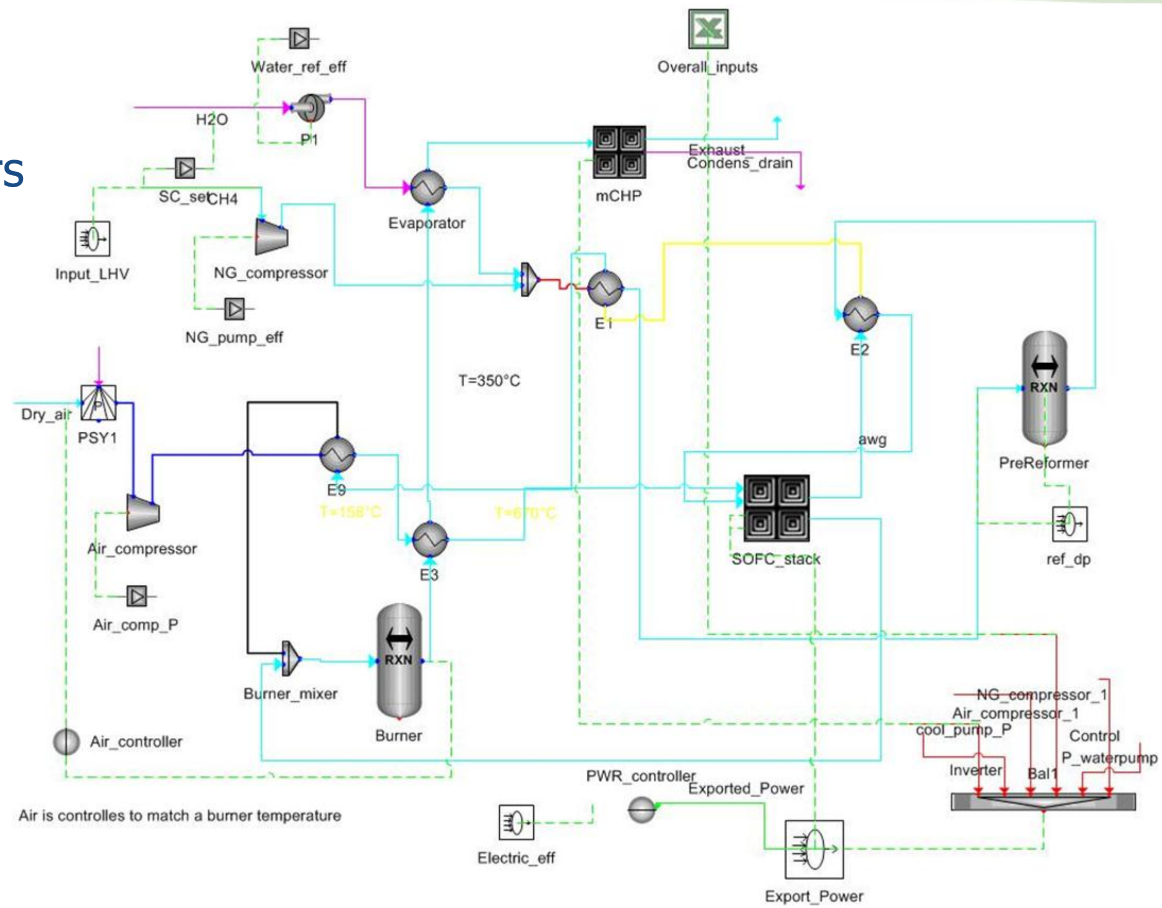
SOFC system component model



ASTERIX III

Design and develop SOFC µCHP

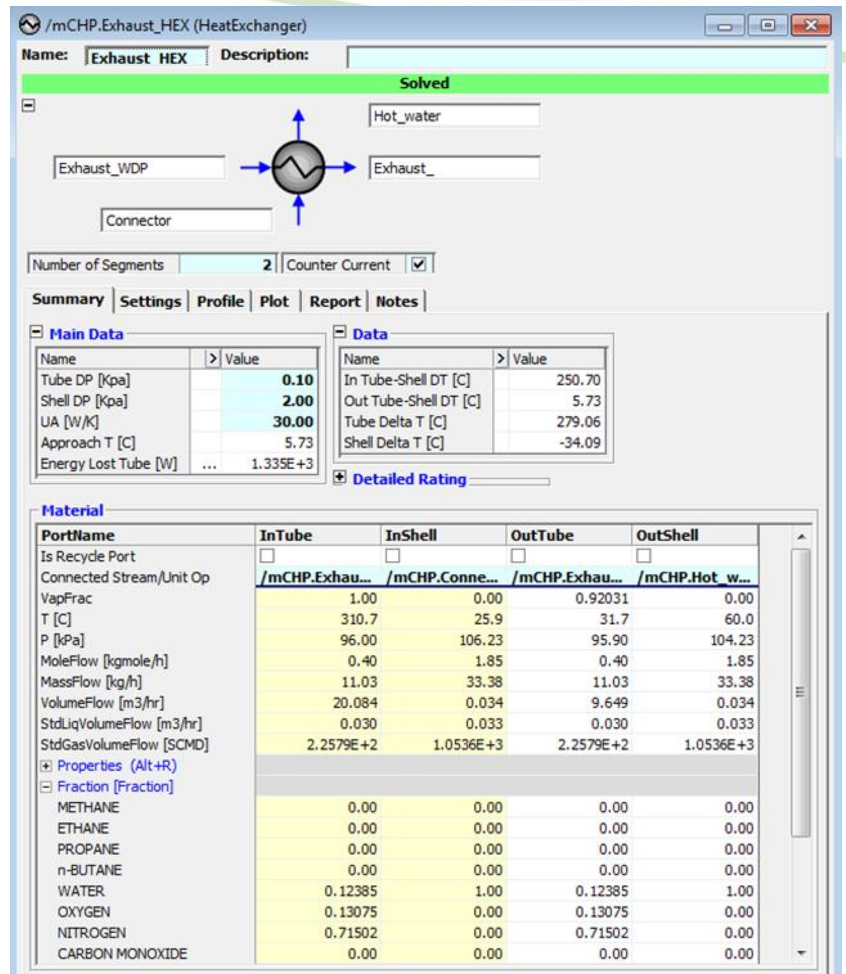
The main flow sheet in the developed SOFC system model (VMGsim), focus is here on Balance of plant components as compressors and pumps are parasitic losses in the system.



ASTERIX III

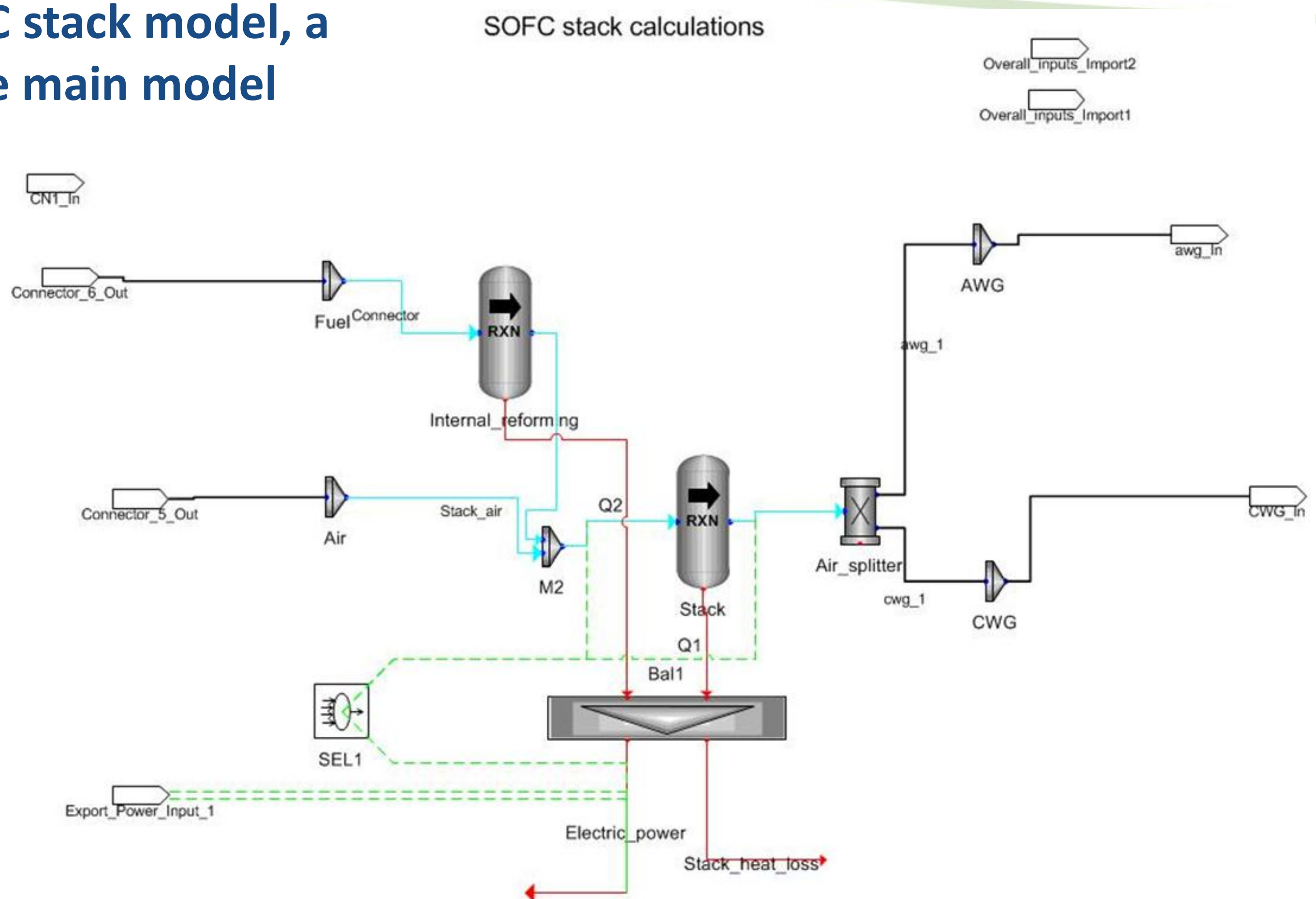
Design and develop SOFC µCHP

A screen shot from the software, that shows the requirements for the exhaust heat exchanger in the heat integration sub assembly



Dantherm Power

A complete SOFC stack model, a sub model to the main model



Asterix3

ASTERIX III
Correlation with MAIP/AIP

AIP 2009: Stationary Power Generation & CHP

Primarily: Proof-of- concept fuel cell systems

Development of proof-of- concept prototype fuel cell systems for any stationary application, potential feature and technology. The aim is to demonstrate feasibility of proposed systems. The aim is to show interaction between the PoC FC systems with other devices required for delivering power, heat and cooling to end users.

- µCHP based on SOFC technology proof-of-concept by simulation, specification, building, optimization, design, develop and test
- µCHP interaction with heat storage
- µCHP interaction with a standard installation
- µCHP interaction with a heat pump solution

ASTERIX III
Correlation with MAIP/AIP

Asterix3
a FCH JU Project

AIP 2009: Stationary Power Generation & CHP

Secondary: Validation of integrated fuel cell systems readiness

Development to show system readiness of integrated fuel cell systems in simulated application environments for typical lead applications. Economic manufacturing solutions need also to be addressed, ensuring that quality and cost targets are met.

- Understanding system level failure modes leading to more robust systems
- Maintenance and repair strategies for robust and reliable systems
- Automatic control, control strategy. heat, electricity ratio, grid connected
- Safety issues, legislation, CE marking, market requirements, legislative issues, feed in tariffs etc.

ASTERIX III

Test and validate SOFC µCHP unit

Test Bench setting-up for SOFC system characterization
(conjunction with heat pump as well)

Geothermal pump

Safety hood

Data monitoring system

AC Electronic load

Desulphurization cartridge

Electric performance monitoring system

Water analysis equipment

- X-rays fluorescence
- X-rays photospectroscopy (dry powders)

Gas analysis equipment

Microgrid simulator with AC and DC electronic load

Public grid

Monitoring system

DC Electronic load

0.5kW Asterix system

ASTERIX III
Cooperation and perspective

ASTERIX I
ASTERIX II
ASTERIX III
ASTERIX IV

- **The cooperation in the ASTERIX III project is a continuation of 5 years R&D relationship between partners**
- **The consortium includes more elements in the value chain:**
  - ↓ **R&D and test lab. - *CNR-ITAE and EIFER***
  - ↓ **Fuel Cell Stack and HoTbox company – *HTceramix***
  - ↓ **System integrator - *Dantherm Power***
  - ↓ **Energy company - *EDF through EIFER***
- **The partners plan a larger demonstration as a continuation of ASTERIX III**
- **The partners are involved in a number of other national and European project related to SOFC technology and µCHP**

Thank you for your attention!

www.asterix3.eu

www.htceramix.ch

olivier.bucheli@htceramix.ch