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In-situ Determination of the Anode Flow Distribution in a SOFC Stack under Nominal Operating Conditions by EIS

Diagnostic tools, 23-24 June 2009, Trondheim, Norway

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Why fuel flow distribution measurements?

- Fuel flow distribution over the cells in a stack
- High electrical efficiency requires high fuel utilisation (≥80%)
- High fuel utilisation: severe demands on flow distribution
  - Differences in cell voltage
  - Local depletion of the fuel
  - Degradation

Why fuel flow distribution measurements?

Important information for stack design

- Manifold channels
- Active area

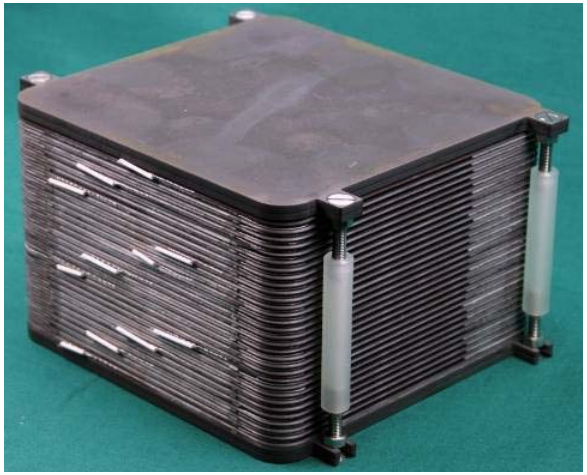
Operation of stack

- Creep & corrosion
- Fuel composition
- Temperature distribution

Stack and experimental conditions

Staxera Mk-100 stack

- 30 cells (ESC)
- Active area: 81 cm²
- Inlet temperature: 750°C
- Outlet temperature: 820°C
- Fuel supply: internal manifolding
- Fuel 40% H_2/N_2 (dry)
- Performance: 810 mV @ 10A (U_f = 53%)
- Voltage measured per block of 3 cells



EIS configuration

Gamry FC350

Kikusui PLZ1004W

I

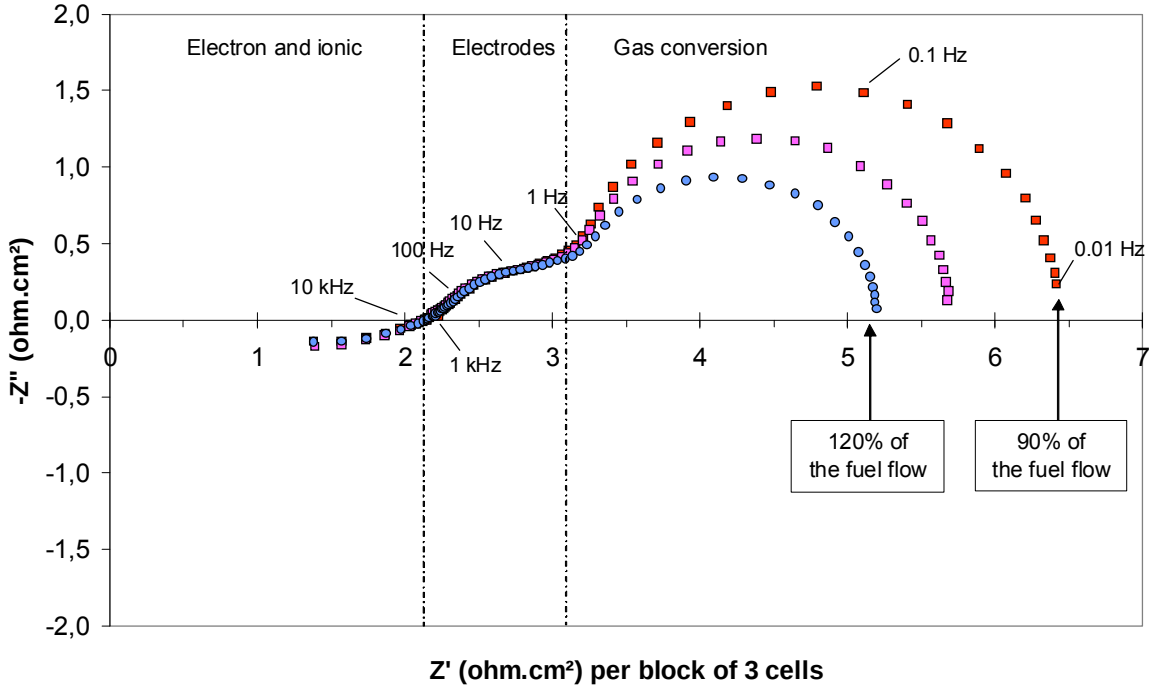
V

Staxera

Stack

Mk-100

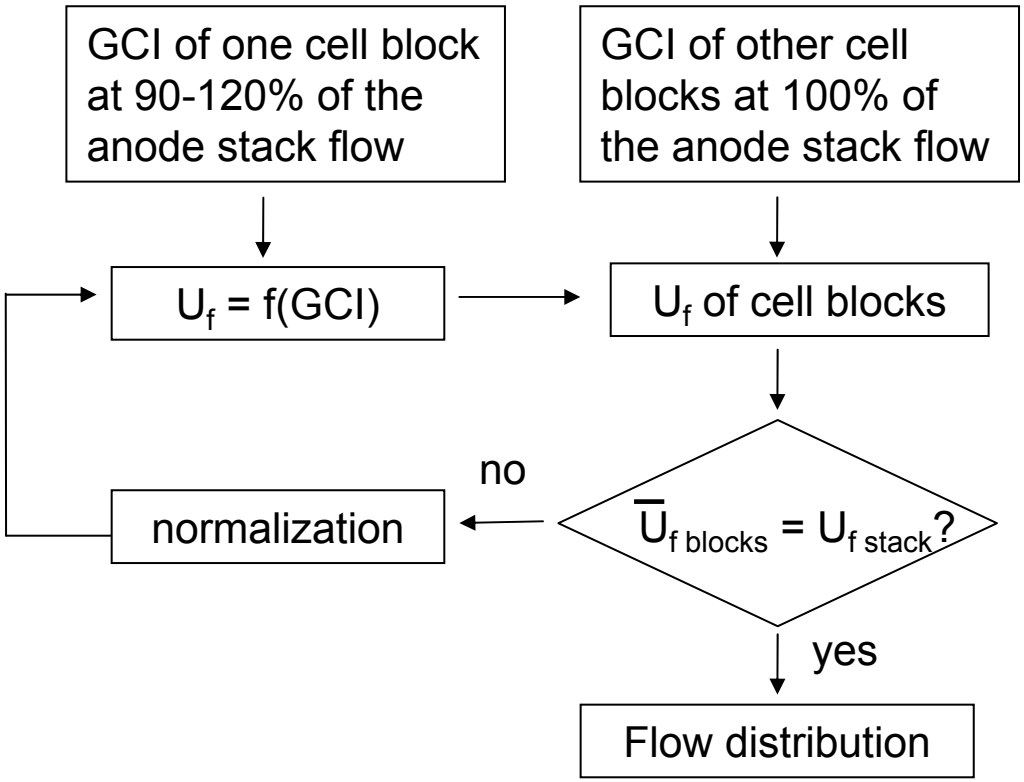
EIS as function of the fuel flow



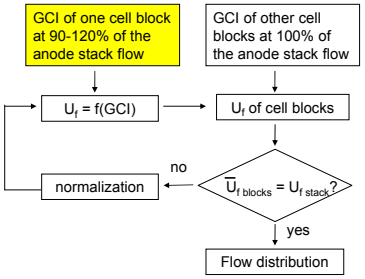
dc=10 A
ac=0.5A
100kHz – 0.01Hz
Fuel: 40%H_2/N_2 (dry)
U_f = 53% (nominal)

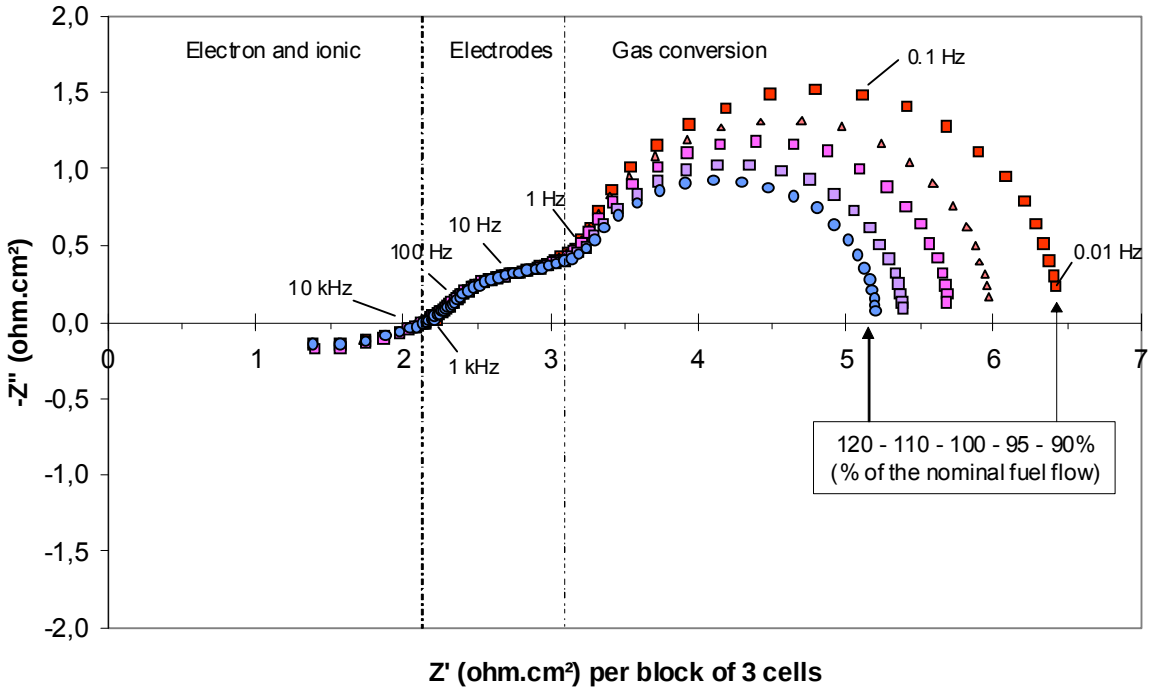
- Gas Conversion Impedance (GCI): measure for the fuel utilisation
- Basis for the determination of the fuel flow distribution

The method


GCI of one cell block at 90-120% of the anode stack flow
GCI of other cell blocks at 100% of the anode stack flow
U_f = f(GCI)
U_f of cell blocks
$\overline{U}_{f\ blocks} = U_{f\ stack}$?
no
normalization
yes
Flow distribution

EIS as function of the fuel flow (1680 hrs)

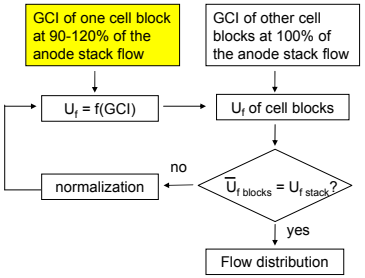


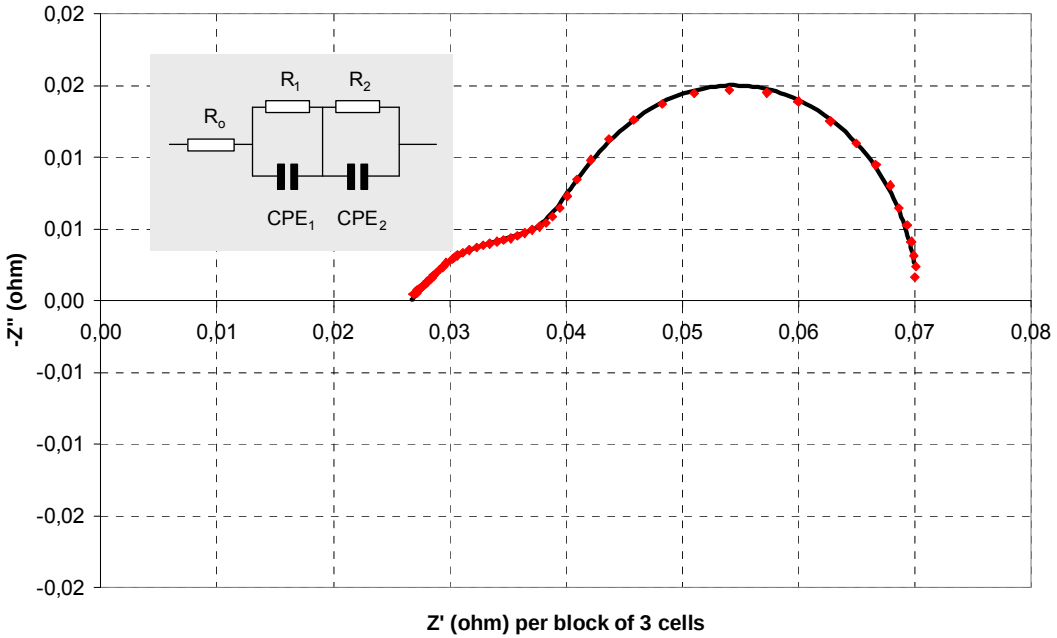


Cell block 4

→ Fit of EIS-spectra for the determination of the GCI values

Fit of the EIS spectrum



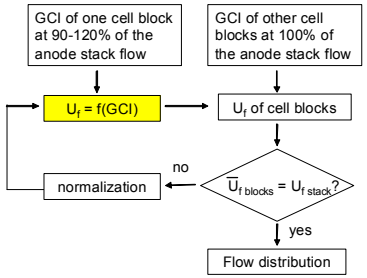


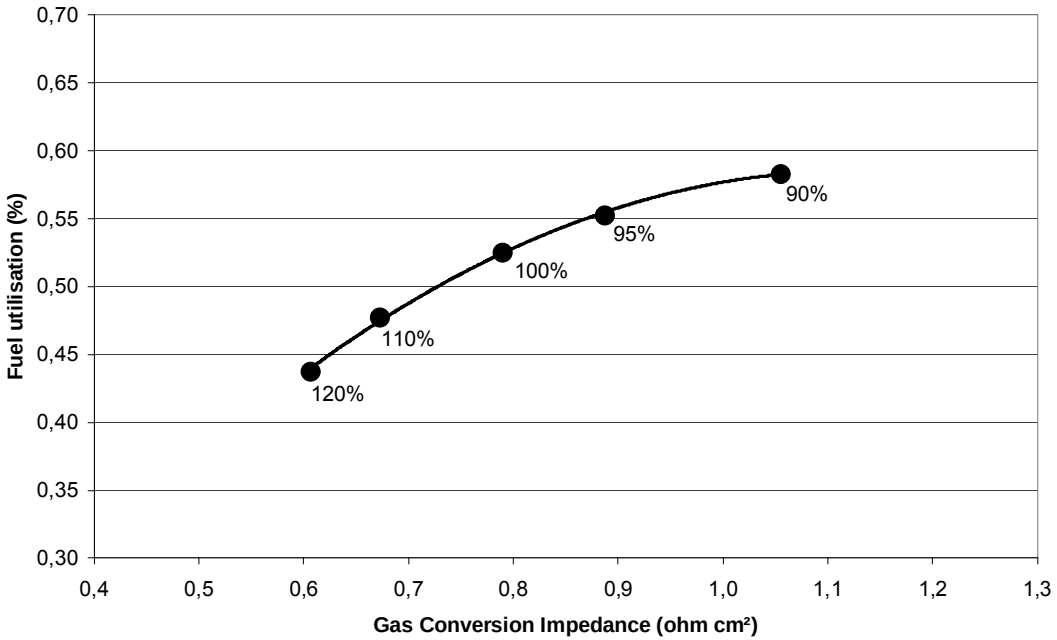
● = measurement, line = fit

R_o	2,2	$\Omega\ cm^2$
R_1	1,2	$\Omega\ cm^2$
CPE_1	7,0	S
n_1	0,58	-
R_2	2,4	$\Omega\ cm^2$
CPE_2	37	S
n_2	0,97	-

→ Fuel utilisation as function of the Gas Conversion Impedance (GCI)

Fuel utilisation as function of the GCI

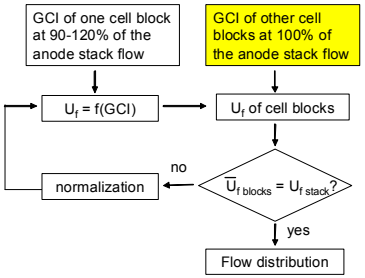


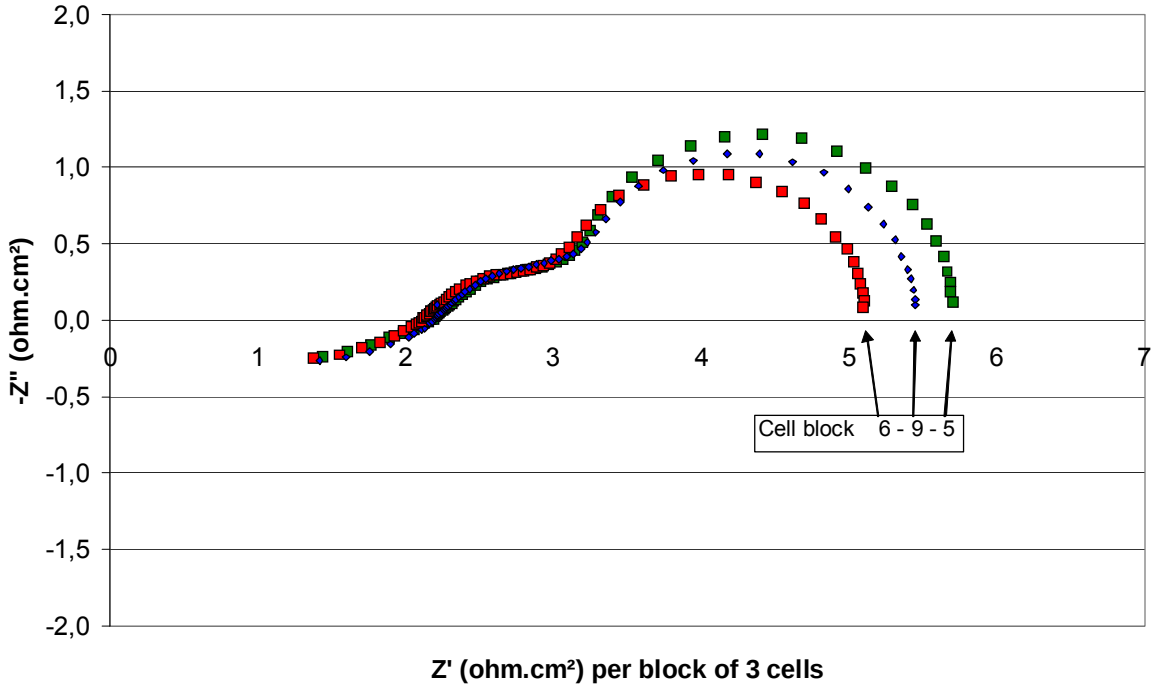


Cell block 4

→ U_f = f(GCI), second order power equation

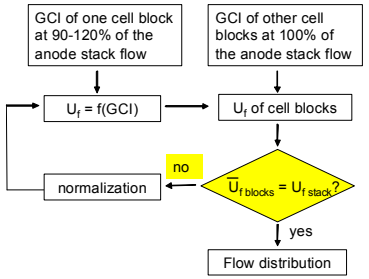
EIS of cell blocks at nominal fuel flow

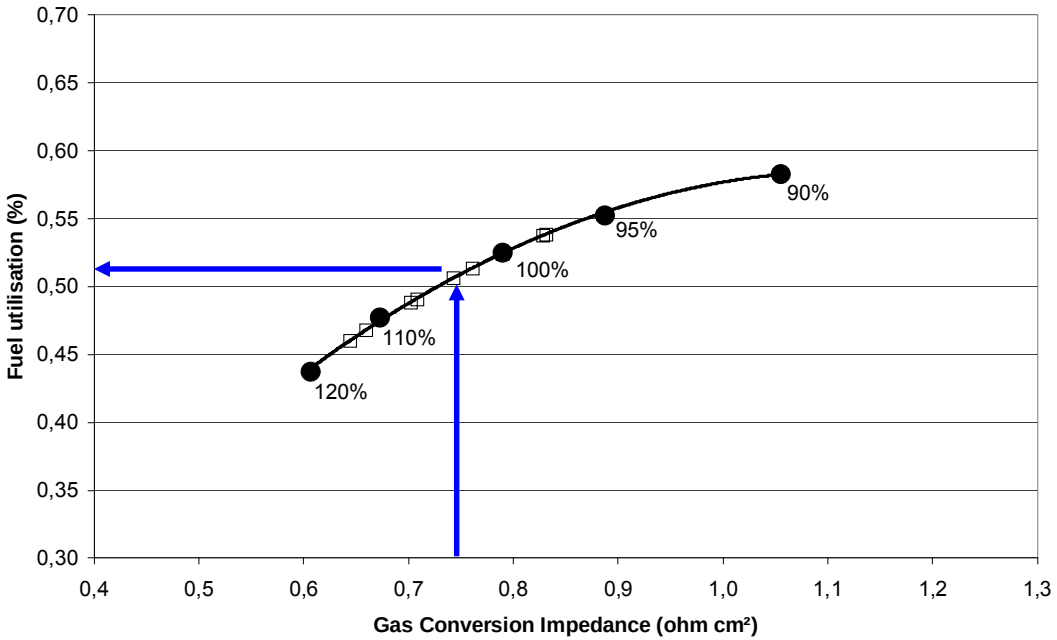




→ Fit of spectra for determination of the GCI values of cell block 1-10

Fuel utilisation as function of the GCI



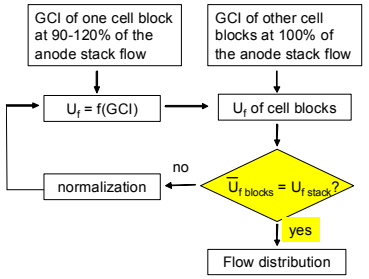


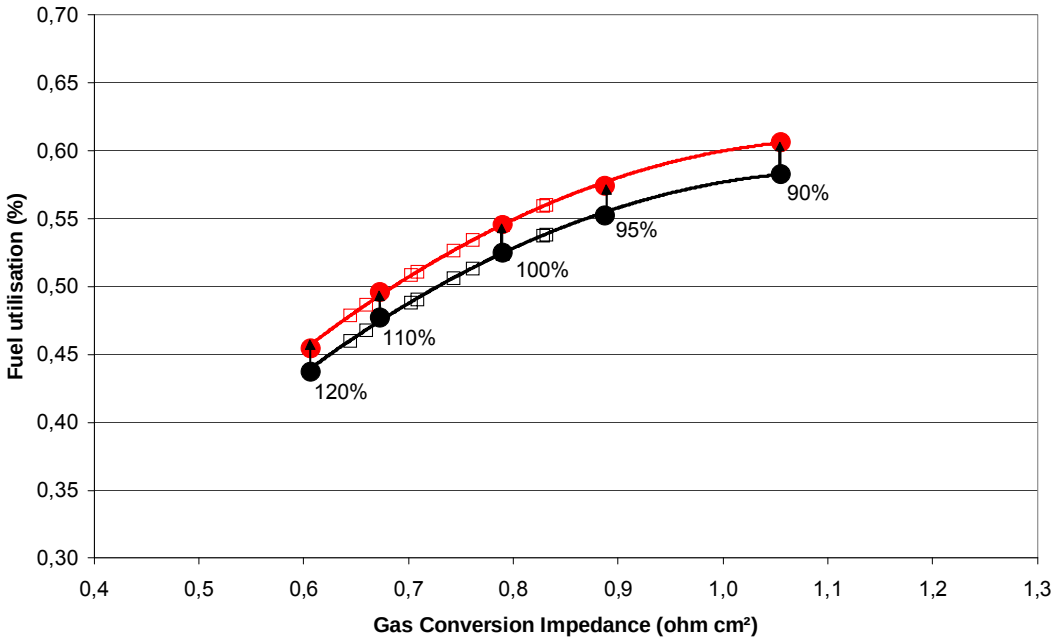
$\overline{U}_{f\ blocks} = 51\%$

$U_{f\ stack} = 53\%$

$\longrightarrow$ normalization

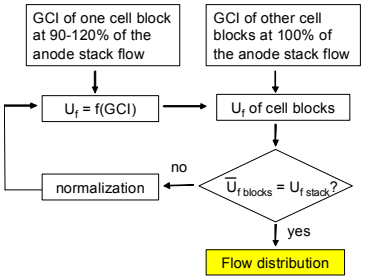
Normalization

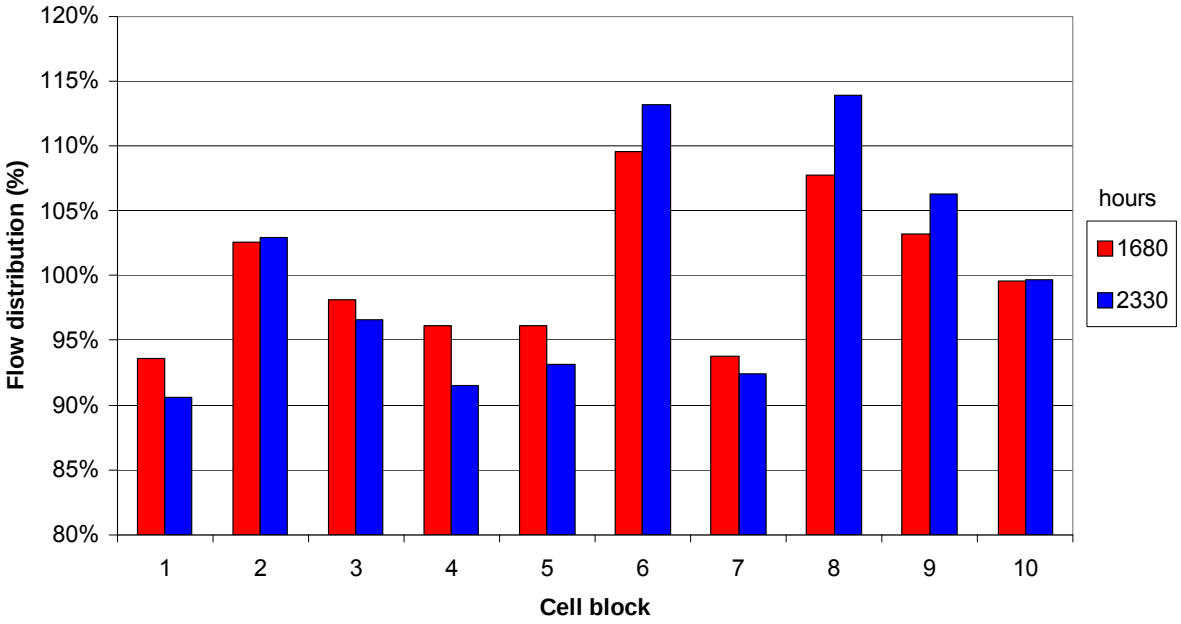




$$\left.\begin{aligned} \overline{U}_{f\ blocks} &= 53\% \\ U_{f\ stack} &= 53\% \end{aligned}\right\} \longrightarrow \text{Fuel flow distribution}$$

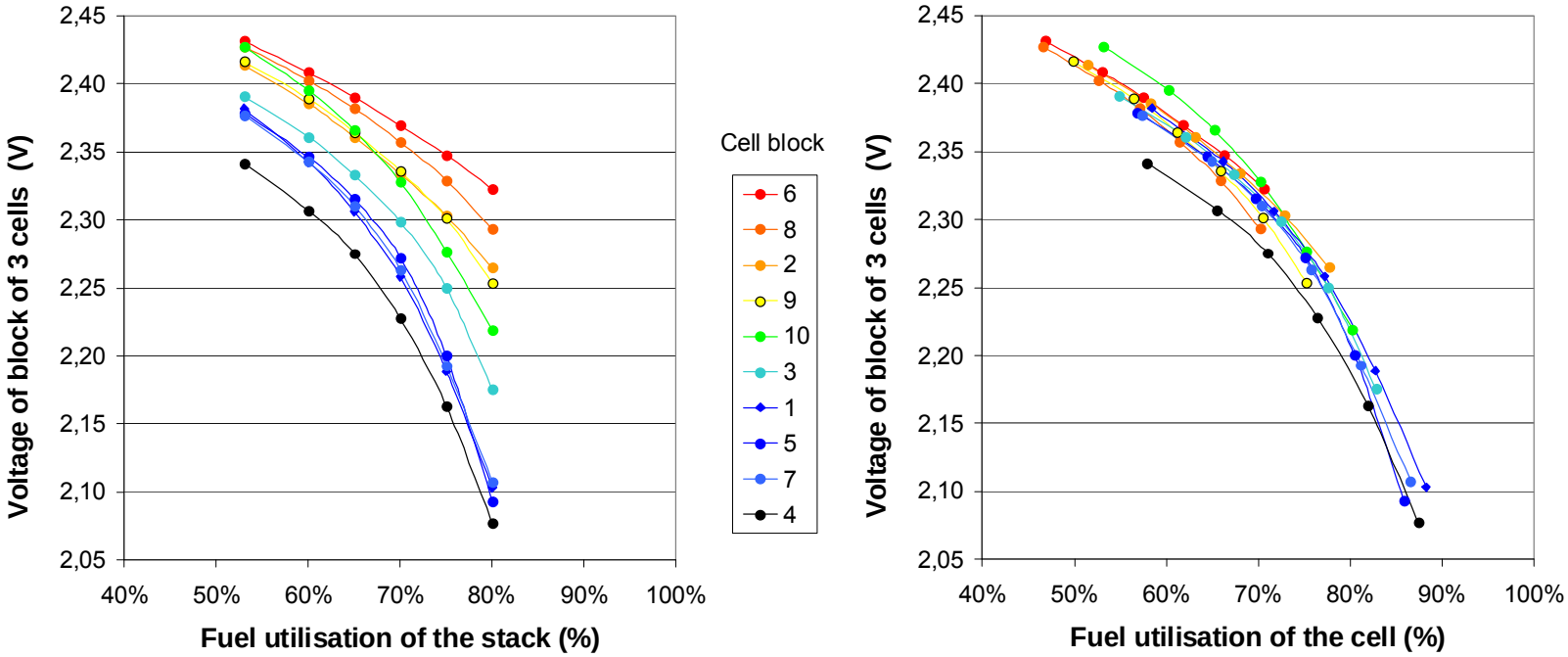
The fuel flow distribution

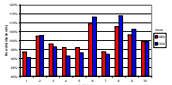




Results hold for this Staxera Mk100 stack; current stacks have improved flow distribution !!

Validation by lowering the fuel flow (10A, 2350 hrs)





Fuel flow distribution

Conclusions

- Easy-to-use method for the determination of the fuel flow distribution in a SOFC stack by EIS at nominal operating conditions:
  - GCI of one cell as function of the fuel stack flow
  - GCI of all cells at the nominal flow → flow distribution
- Validity shown by increasing the fuel utilization
- Simple tool for characterisation of a stack initially and in time without disturbing the nominal operating condition

Acknowledgement

This work was carried out as part of the EU project GreenFuelCell. The authors would like to thank the European Commission for their financial support of this work.