# METSOFC

## "Development of next generation metal based SOFC stack technology"

# GA no: 211940

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# Project and Partnership Description METSOFC

**Main objectives in METSOFC:**

- Development of novel metal-supported cell and stack SOFC tech nology based on product definitions and test protocols defined by APU end users.
- Development and optimize novel materials, design and manufacturing processes for metal based SOFC stack prototypes governed by crucial product requirements.

TOPSOE FUEL CELL
*clean, efficient and reliable*

Risø DTU
National Laboratory for Sustainable Energy
DTU

SANDVIK

osprey

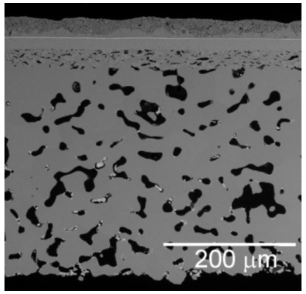
Chalmers University of Technology

Universität Karlsruhe (TH)
Research University · founded 1825

AVL

# Project goals, targets and milestones

**Ceramic based**
**Anode-supported cell**




| |
|---|
| LSCF |
| CGO |
| YSZ |
| Ni+YSZ |

**Metal-supported cell**
***"beyond State of the Art"***

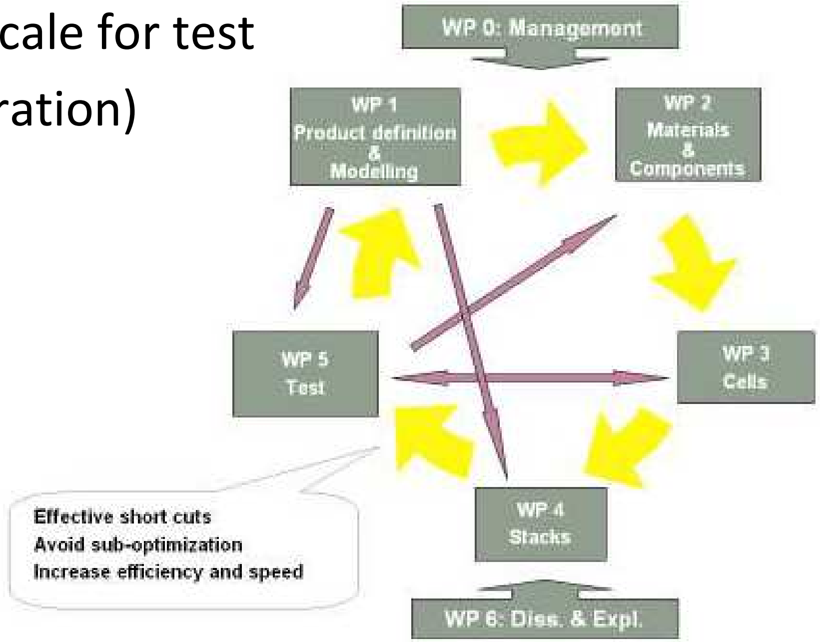
| |
|---|
| **LSCF** |
| **CGO** |
| **ScYSZ** |
| **Novel anode** |
| Stainless steel |

- **Improved functionality**
- **Improved reliability**
- **Improved robustness**
- **Reduced cost**
  Cost effective materials
  Cost effective processing

# Technical Approach

**LEAN Development**

- Project groups (WPs) with a strong background competences
- Vertical integrated project structure (no overlap between partners)
- Several links to other SOFC projects (EU, national, in-house)
- Rapid cell and stack prototypes at optimal scale for test
- Rapid critical optimization loops (critical iteration)




Critical iteration (Lean spirals)
based on new acquired knowledge
Effective short cuts for rapid feedback of
information and results

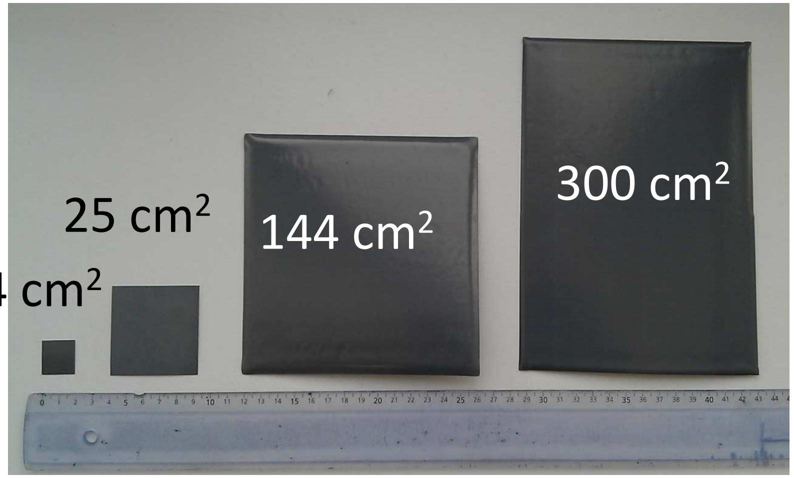
# Technical accomplishments

## *Metal supported SOFC fabrication*

Vacuum furnace sintering

Major challenge:
Co-sintering technology

Up-scaling cells



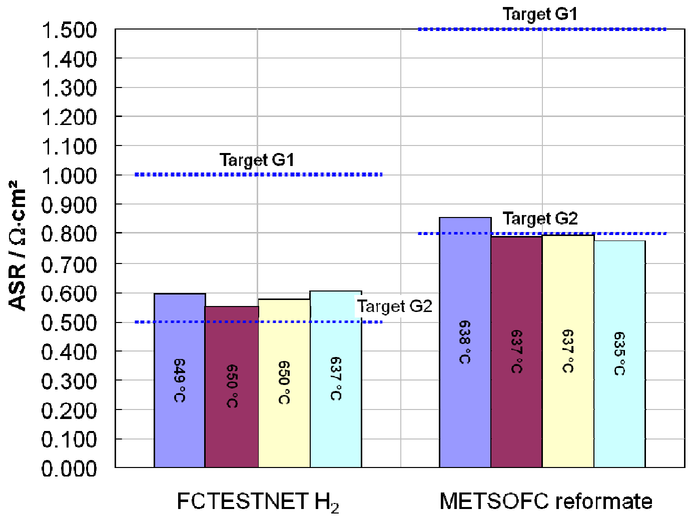

Year

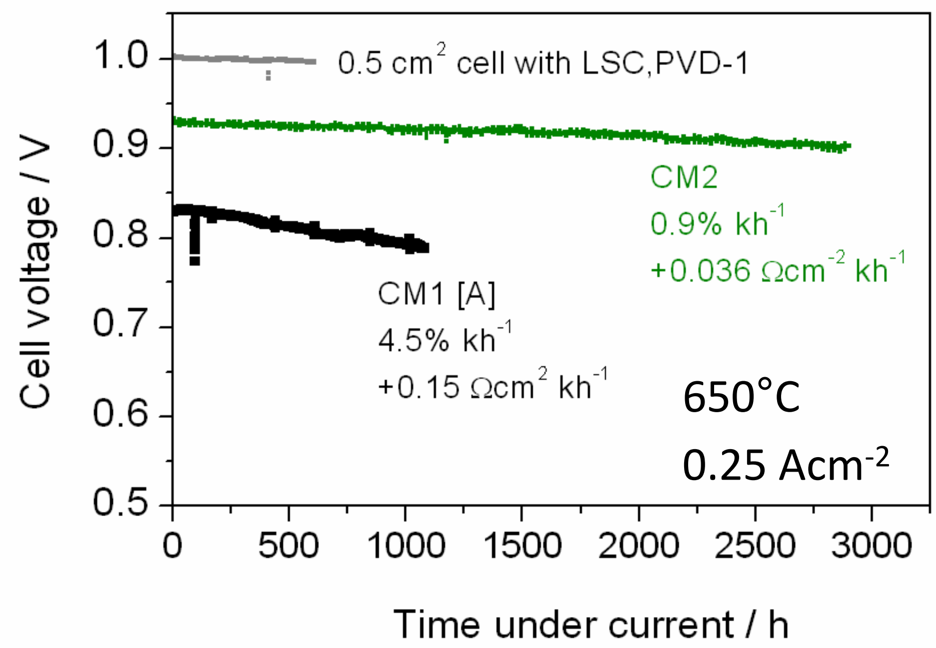
2008 2011

# Technical accomplishments

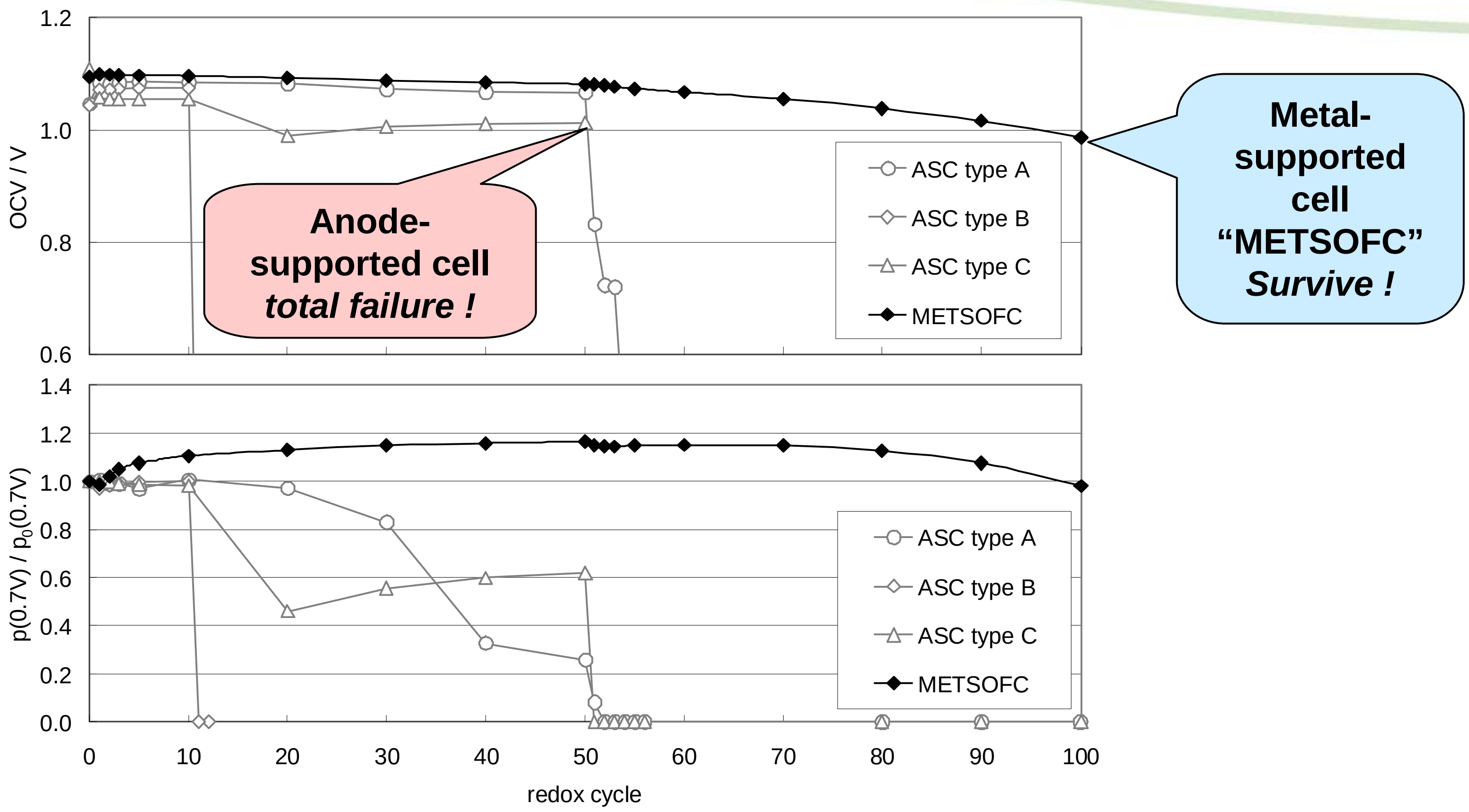
*Cell performance and durability*

Initial Performance of 16 cm² SoA-Cells
ASR-Values



# Robustness:
# Red-ox stability of ASCs

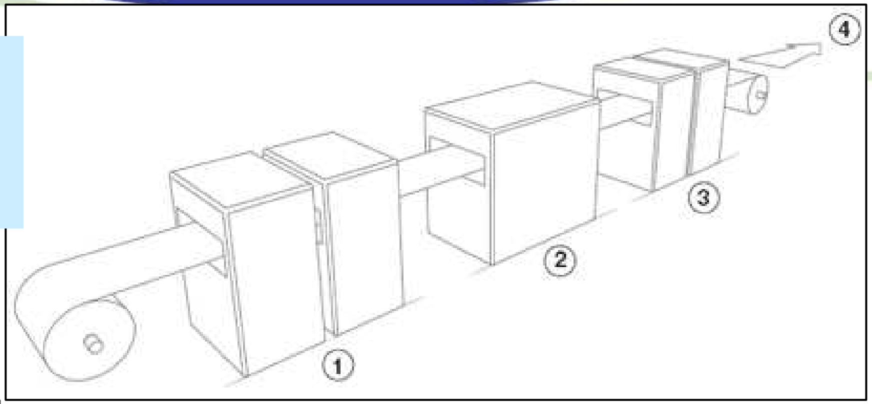


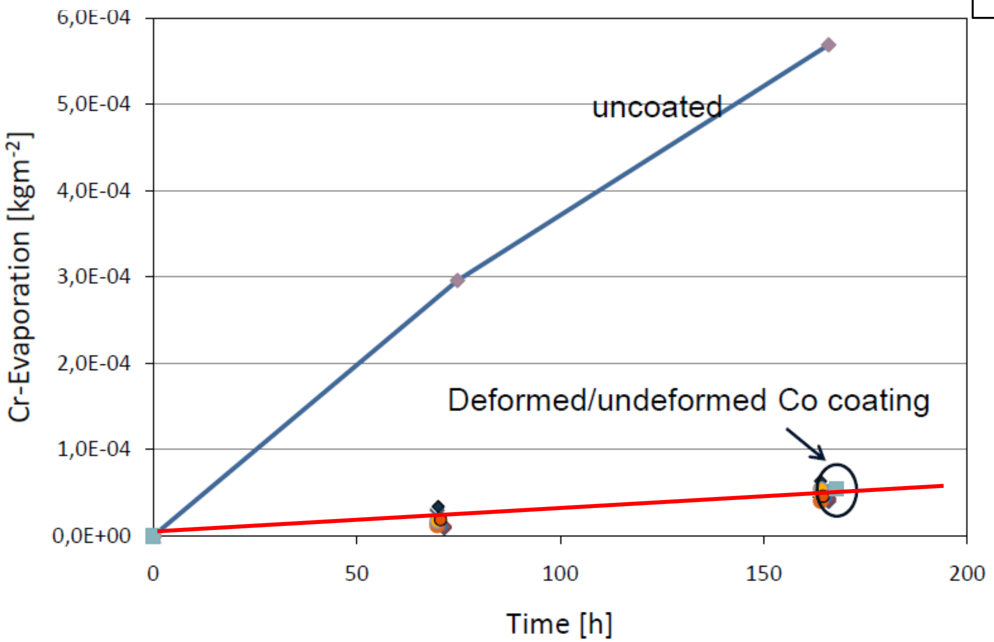

**Red-ox stability of ASCs (Ni/YSZ anode substrate) and metal supported SOFCs : OCV (top) and performance degradation (bottom), tested at 800 °C**

# Technical accomplishments
## *Stack development and interconnects*

**Metallic interconnect development**

**Sandvik continuous thin film coating on strip steel by PVD**



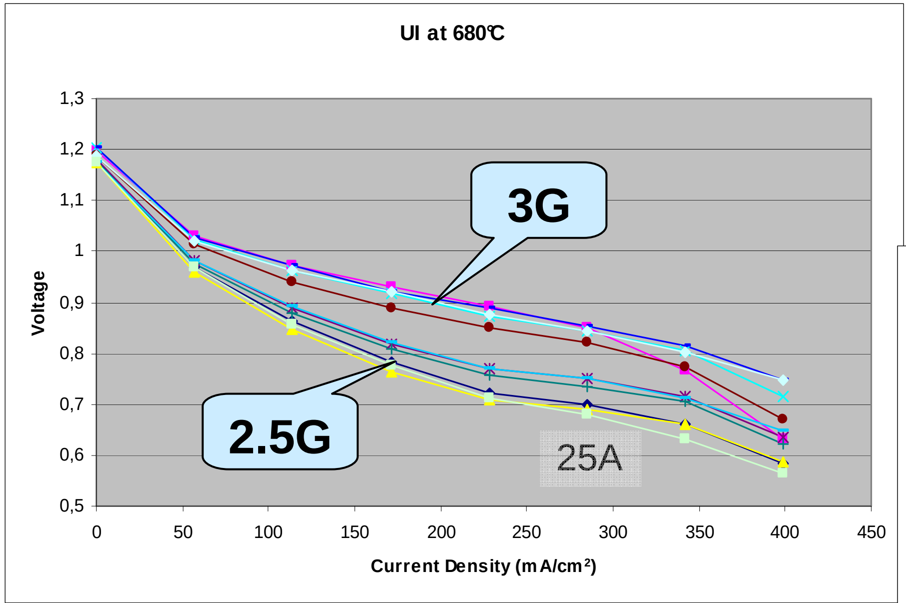



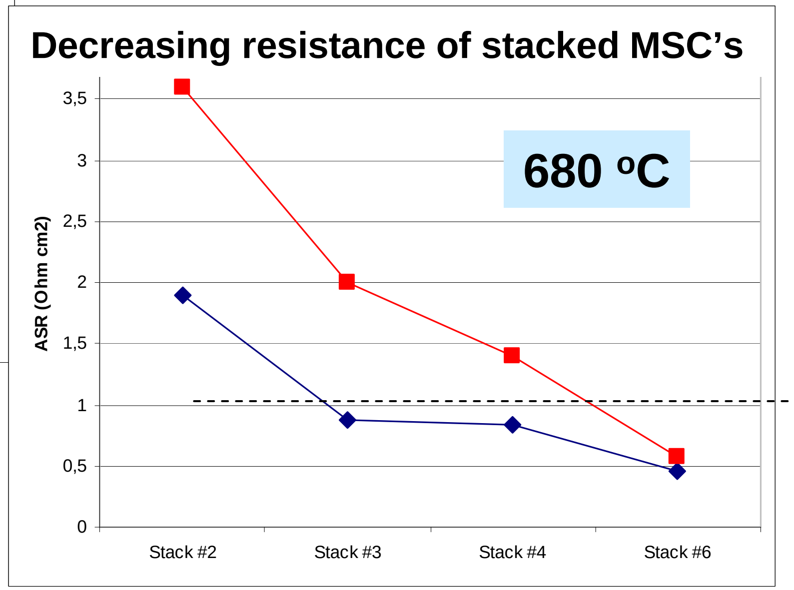

**Interconnect shaping of pre-coated stip steel**

# Technical accomplishments

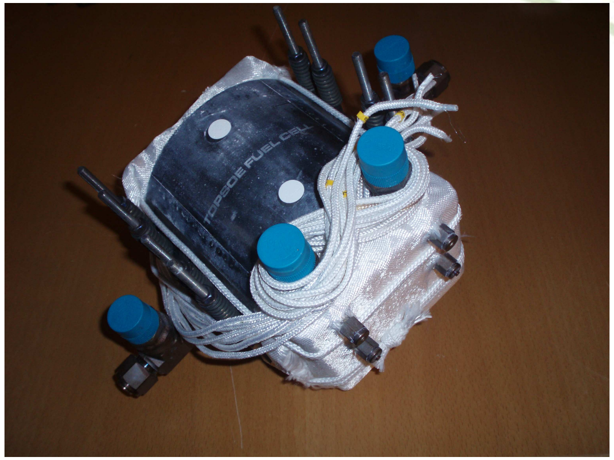
## *Stack results*

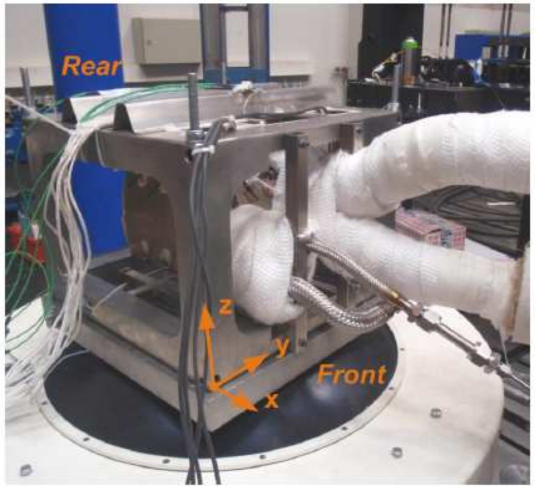
**MSC (3G) Better Cell Performance than 2,5G** (state of the art anode-supported cell)



# Hot vibration test
(AVL, Gratz Uni. - EU METSOFC project)






## Transportation applications

| | | |
|---|---|---|
| Redox cycles @Operating Temp. | >30 | major system malfunction, shut down under oxygen environment |
| Deep Thermal cycles (temperature <100°C) | >300 | full cool down, approx. 1x per week |
| Medium Thermal cycles (temperature >100°C) | >3000 | cool down phases, when no current is requested from operator |
| Warm-up | <30 min | |
| Stack Costs | < 200 US$/kW | costs for system integrator |

# Technical accomplishments

## *Progress towards performance indicators*

| Components | Targeted performance values |
|---|---|
| **Metal supports** | **Surface area**<br>< 0.02 $m^2$/g, (25% porosity)<br>Corrosion weight gain and oxide thickness of metal support<br>< 0.4mg/$cm^2$ (after 1000 h, 850°C at simulated 90% FU)<br>< (coated materials) |
| Cells G1 | Performance ASR<br>< 1 $\Omega cm^2$, (650 °C)<br>< 1.5 $\Omega cm^2$, (650 °C, reformate)<br>$\Delta$ ASR < 3% / 1000 h<br>**Mechanical**<br>Strength > 250 MPa<br>Weibull > 10 |
| Cells G2 | Performance ASR<br>< 0.5 $\Omega cm^2$, (650 °C)<br>< 0.8 $\Omega cm^2$, (650 °C, reformate)<br>$\Delta$ ASR < 0.05% / 1000 h<br>**Mechanical**<br>Strength > 350 MPa<br>Weibull > 15 |
| **Interconnect materials** | Corrosion cyclic oxidation in air, weight gain, ASR, Cr loss<br>Total Cr loss (hours until 16% Cr bulk content)<br>Weight gain < 0.1 mg/$cm^2$ kh. |
| Stacks | Performance ASR<br>< 0.8 $\Omega cm^2$ (or not more than 0.2 higher than for the cell)<br>$\Delta$ ASR < 3% per kh, (< 1% per kh)<br>**Mechanical**<br>$\Delta$ ASR (OCV, number of broken cells)<br>**Up-scaling**<br>Two next gen (2G+) 50 cell stacks |

**All development steps are characterized by targeted performance values and compared with presented SoA data in literature.**

Best (published) performance and durability of MS-SOFC

** Not published data*

| Institute | Active area ($cm^2$) | Temperature (°C) | Power density* (W/$cm^2$) | Degradation |
|---|---|---|---|---|
| Risø DTU | 0.5<br>16<br>82 | 650<br>650<br>680 | 1.14 (at 0.6V)<br>0.60 (at 0.6V)*<br>0.25 (at 0.85V)* | 1%/kh |
| DLR et al. | 12.56<br>81.4 | 800 | 0.609 (at 0.7V)<br>0.384 (at 0.7V) | 2.5%/kh |
| Plansee, Jülich | 1<br>16<br>80 | 800-820 | 1.064 (at 0.7V)<br>0.530 (at 0.7V)<br>0.840 (at 0.7V) | Issues with low OCV |
| KAIST | Button cell | 800 | 0.6 | |
| Ikerlan | 4-16 | 800 | 0.45 | |
| Ceres | | 570 | 0.14 (at 0.75V) | |
| NRC Canada | Button cell<br>16 | 650 | 0.53<br>0.27 | Issues with low OCV |

# Dissemination activities

**The METSOFC project has been presented in presentations and posters at a number of international conferences and research networks**

- More than 20 presentations and posters at conferences
- More than 10 peer reviewed papers in relevant scientific journals
- METSOFC project presented at various national strategy group meetings on SOFC.

# Next Generation SOFC development
## Future perspectives

Collaboration platform

- EU SCOTAS SOFC
- EU DESTA
- EU METPROCELL
- EU EuroFC-Life

**EU METSOFC Cell**
2008 -2011
**5000 h lifetime**
**Mobile applications**

**EU METSAPP Cell**
2012 – 2014
**40.000 h lifetime**
**Stationary applications**