RELIABLE FUEL CELL PERFORMANCE FROM BASIC PHENOMENA TO SYSTEM MANAGEMENT

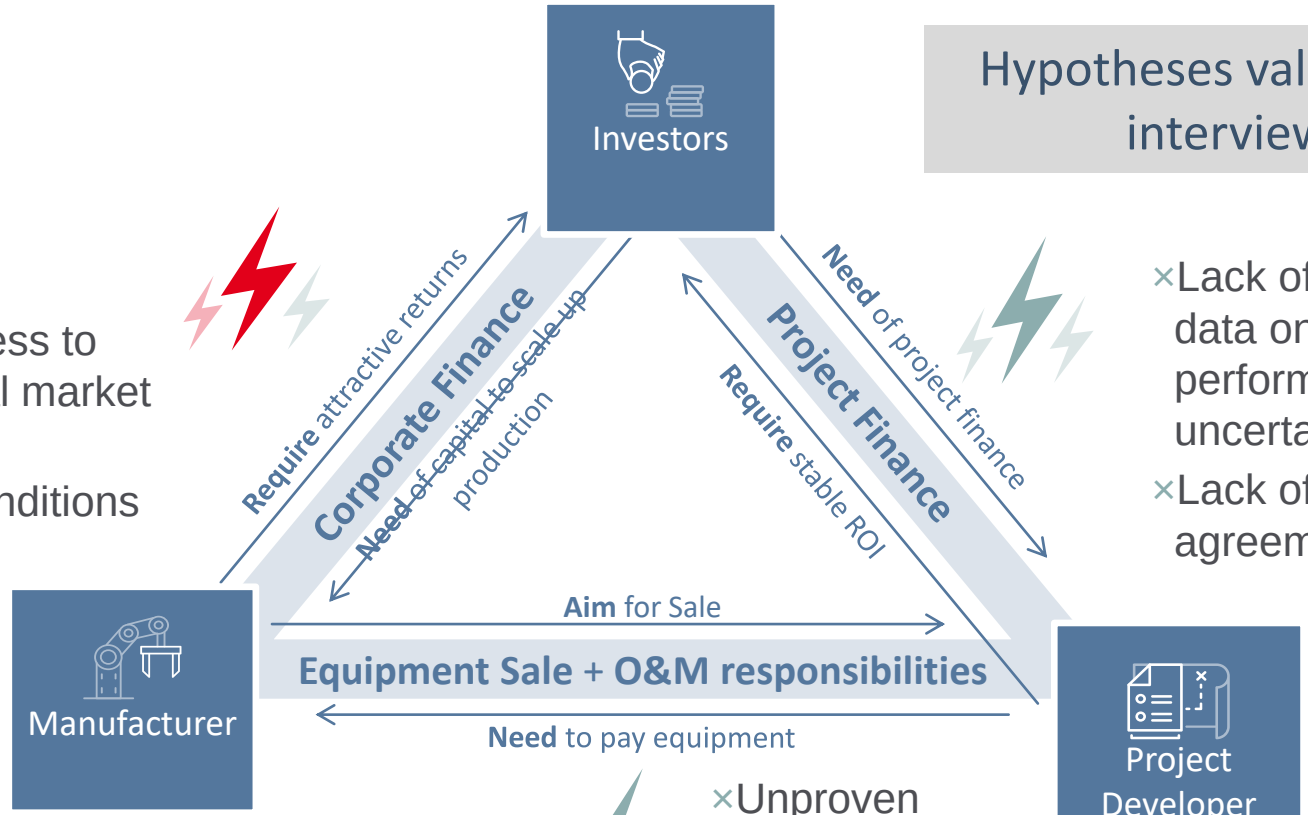
S. J. McPhail – C. Pianese (UNISA) – D. Pumiglia (ENEA)

A WORLDWIDE TECHNOLOGICAL CHALLENGE

- Useful lifetimes of >80kh expected/needed for commercial fuel cell stacks (stationary CHP and energy storage applications)
- Achievable through:
  - more reliable system design, control, diagnostic tools
  - addressing intrinsic degradation of the cell assembly
- No reliable degradation models currently available nor validated test procedures to predict durability in a practical timeframe
- Resource- and time-consuming real-time durability tests required for verification of material/component modifications
- Accelerated tests with reproducible transfer functions to real-life operation required
- 1000h stack test = approximately 10 k€ operational costs. Typical testing times are 15 kh for industry qualification. AIM: reduce to 3kh and 120k€ can be saved per test.

A WORLDWIDE COMMERCIAL CHALLENGE

- Uncertain and unproven technologies cause a vicious circle



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A WORLDWIDE COMMERCIAL CHALLENGE

- Innovative insurance solutions cover risks that will enable sustainable business growth

Long-term guarantees

Product Guarantee

- ✓ Protection against part breakdown
- ✓ Coverage of maintenance and replacement intervals
- ✓ Cost overrun O&M plan

Performance Guarantee

- ✓ Protection against underperformance
- ✓ H2 Production Rate
- ✓ Efficiency/Cell voltage

Availability Guarantee

- ✓ Protection against under availability
- ✓ Covers downtime
- ✓ Project-specific/on site spare parts

→ ~~Un~~proven technology
→ ~~Lack of~~ standards
→ ACCELERATED TESTS

*Excluding outside factors (e.g. grid)

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A WORLDWIDE TECHNOLOGICAL CHALLENGE

- A great number of operational parameters influence SOC degradation, each contributing according to **characteristic times and intensities**, often in convoluted or even contrasting fashion
- The closely knit processes in a working SOC (CHP & P2X) often lead to domino-effects, whereby acute degradation occurring in one component or area can trigger or accelerate degradation elsewhere in the stack. → Focus on critical components for systematic assessment of effects

- **Critical components** limiting SOC stack lifetime:
  - Fuel electrode
  - Oxygen electrode
  - Interconnect

DEGRADATION PHENOMENA: THE FUEL ELECTRODE CASE

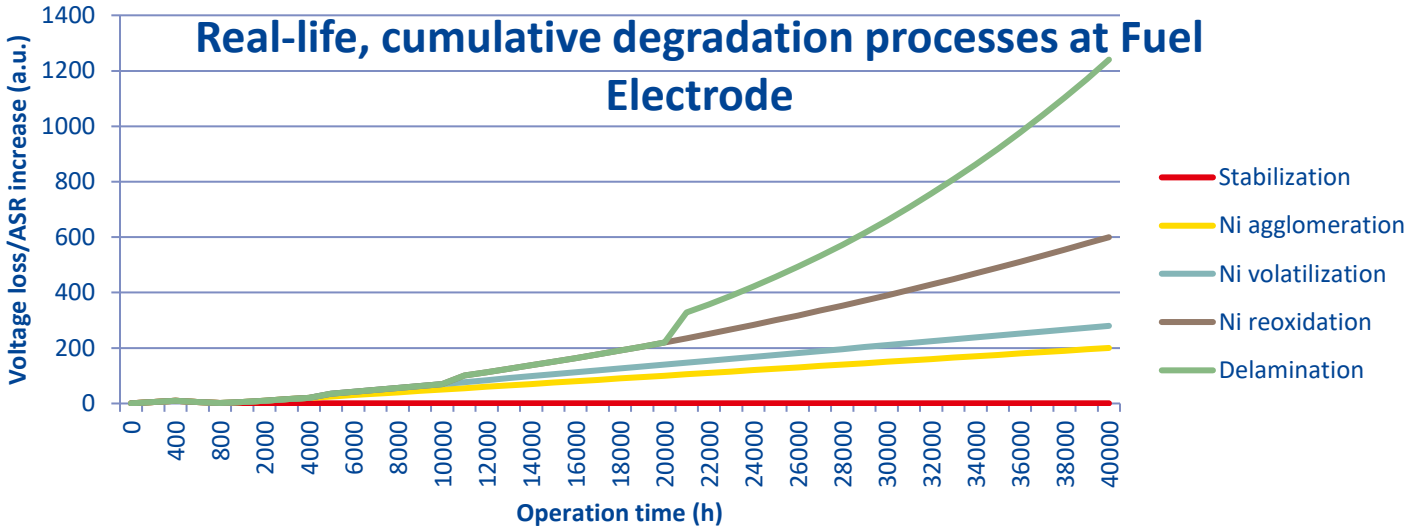
- Fuel electrode

COMPONENT	LOCATION	*OPERATIONAL DEGRADATION*			CRITICALITY (1 low-5 high)	ACTIVATION
		Effect	SOFC MODE	SOEC MODE		
Fuel Electrode	Functional layer	Ni agglomeration	Morphological instability	equal to SOFC	4	thermal
	Functional layer	Ni depletion	Volatilization; loss of Ni percolation	equal to SOFC	4	thermal/ chemical
	Support	Reoxidation	leakage @ seal interface due to seal degradation	likely equal to SOFC	2	is a seal problem!
	Support	Reoxidation	leakage @ seal interface due to thermal cycling mechanical stress	unlikely due to little thermal cycling operation;	2	is a seal problem!
	Functional layer/ electrolyte	Delamination	equal to SOEC	YSZ fragilisation	2	mechanical

- Decrease in TPB length → activation losses
- Decrease of electrical conductivity → ohmic losses
- Fuel leakage, starvation, cross-leakage → mass transport losses

ACCELERATED STRESS TESTS: WHY?

- Fuel electrode



- **Accelerated Stress Test aims to:**
  - Design and verify component improvement with time/cost effectiveness
  - Build reliable models for Remaining Useful Life prediction
  - Improve stack/modules Diagnostics, Control and Real-Time Optimization hardware & software

ACKNOWLEDGEMENTS

This project has received funding from the Fuel Cells and Hydrogen 2 Joint Undertaking under **Grant Agreement No 825027**. This Joint Undertaking receives support from the European Union's Horizon 2020 research and innovation programme and Hydrogen Europe.

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