CRESCENDO - Critical Raw material Electro-catalystS replacement ENabling Designed pOst-2020 PEMFC

D. J. Jones[1], A. Roy[1], M. T. Sougrati[1], Nicolas Donzel[1], P. Y. Blanchard[1], F. Jaouen[1], J. Sharman[2], G. Spikes[2], A.M. Bonastre[2], D. Fongalland[2], L. Smith[2], M. Primbs[3], Y. Sun[3], P. Strasser[3], A. Mehmood[4], A. Kucernak[4], S. Agnoli[5], L. Calvillo[5], T. Kosmala[5], G. Daniel[5], G. Granozzi[5], C. Durante[5], A. Orfanidi[6], B. Reuillard[7], V. Artero[7]

[1] CNRS Montpellier, [2] Johnson Matthey Fuel Cells, [3] Technical University of Berlin, [4] Imperial College London, [5] Università di Padova, [6] BMW Group, [7]CEA/Grenoble

BACKGROUND
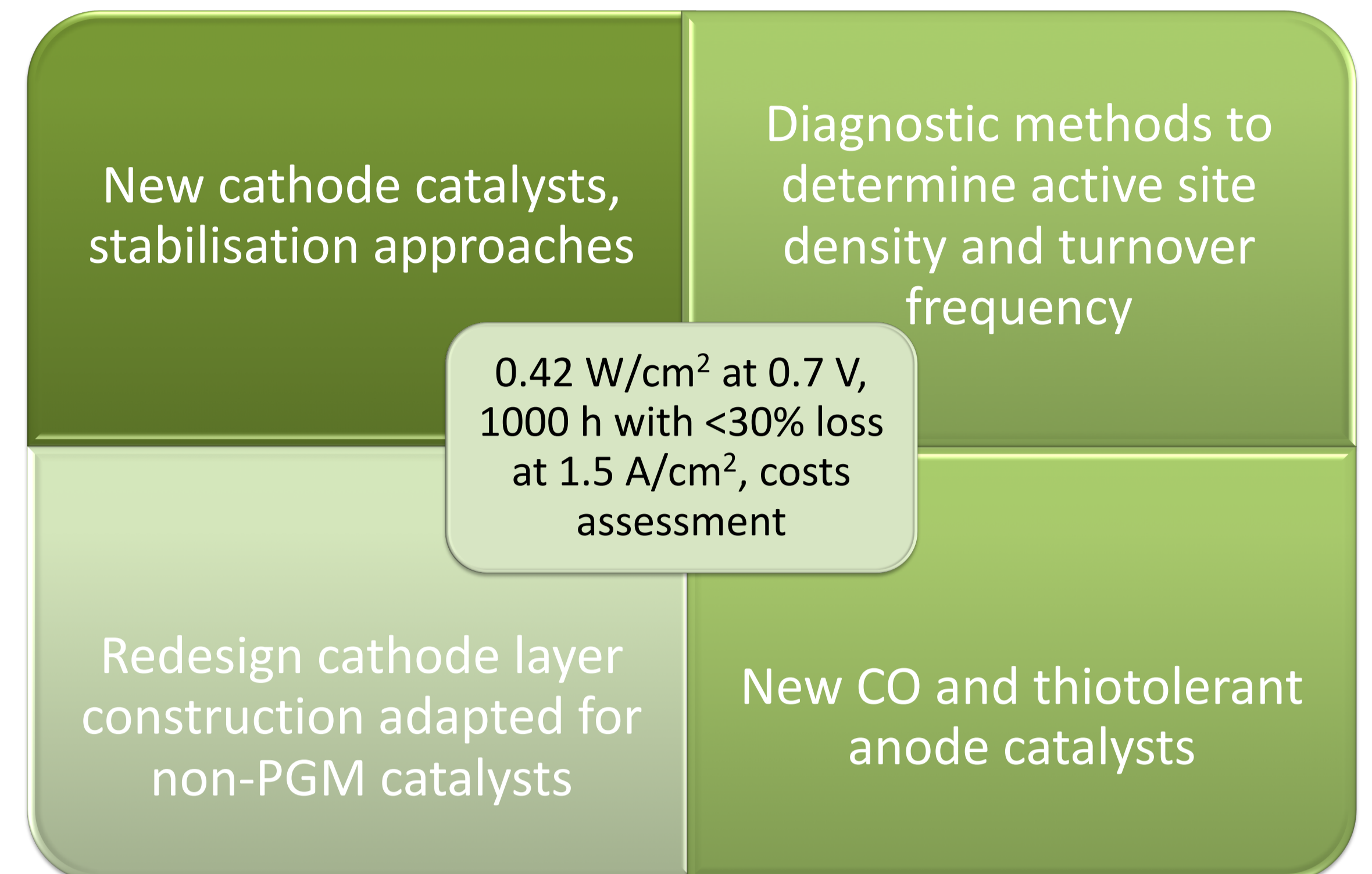

Pt, Ir, Rh, Pd are the rarest elements in the earth's crust
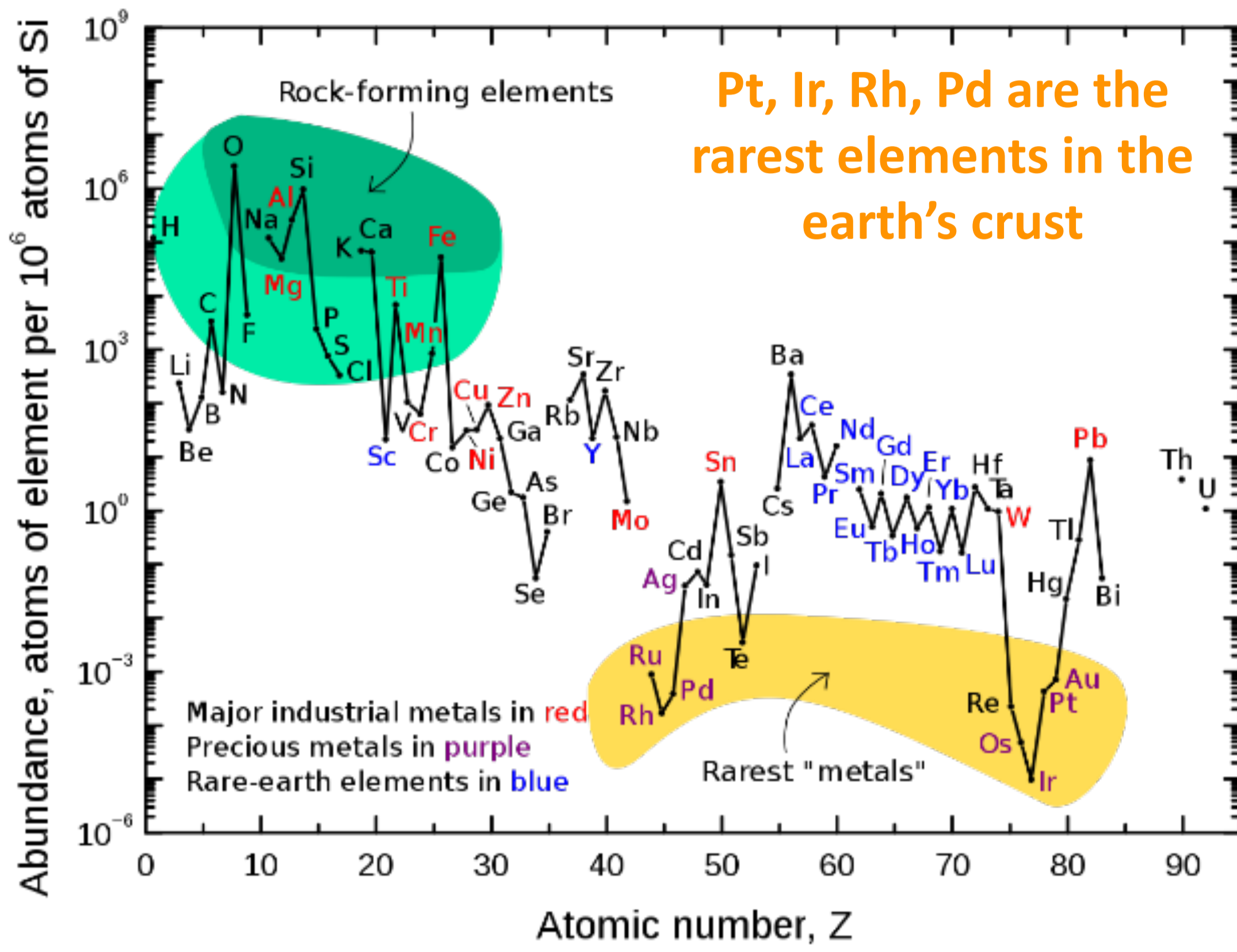
Can non-PGM catalysts provide competitive fuel cell performance and cost effective FC catalysis ?

✓ Increase **activity and active site density**

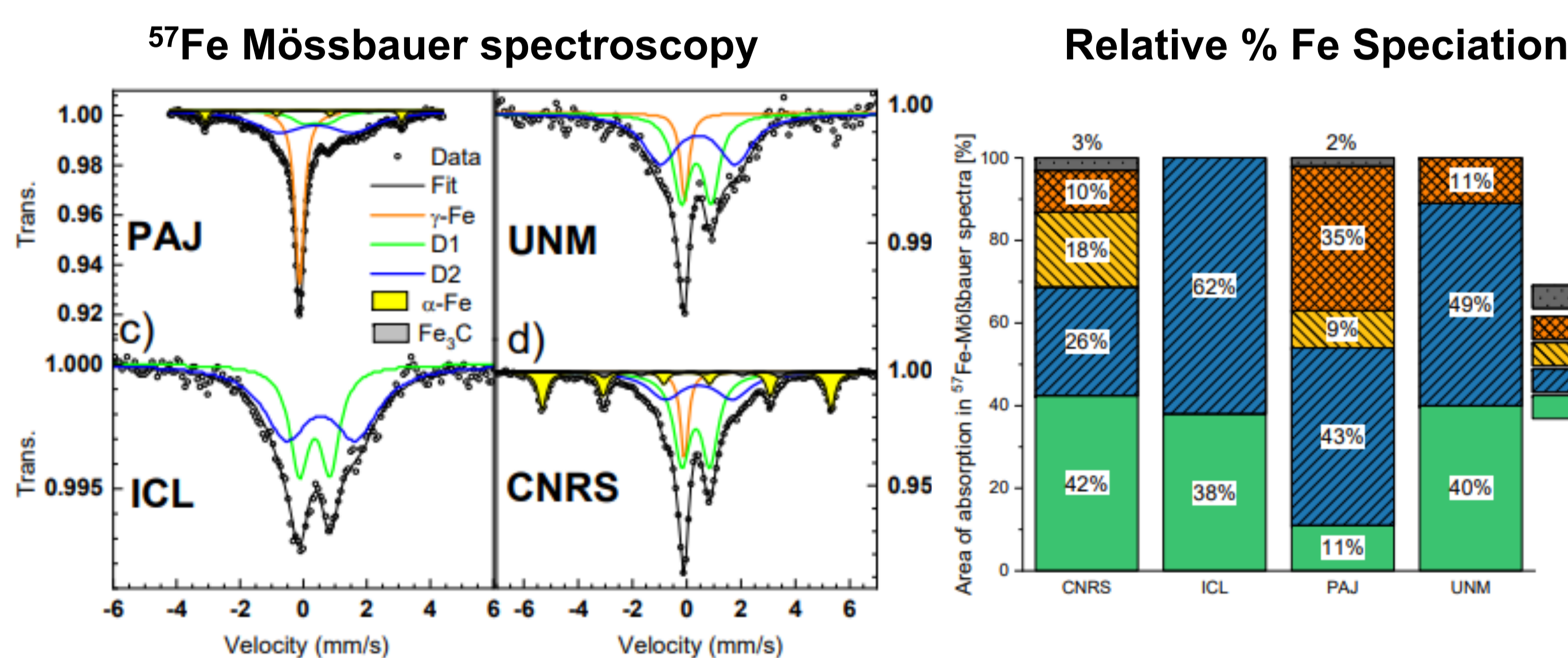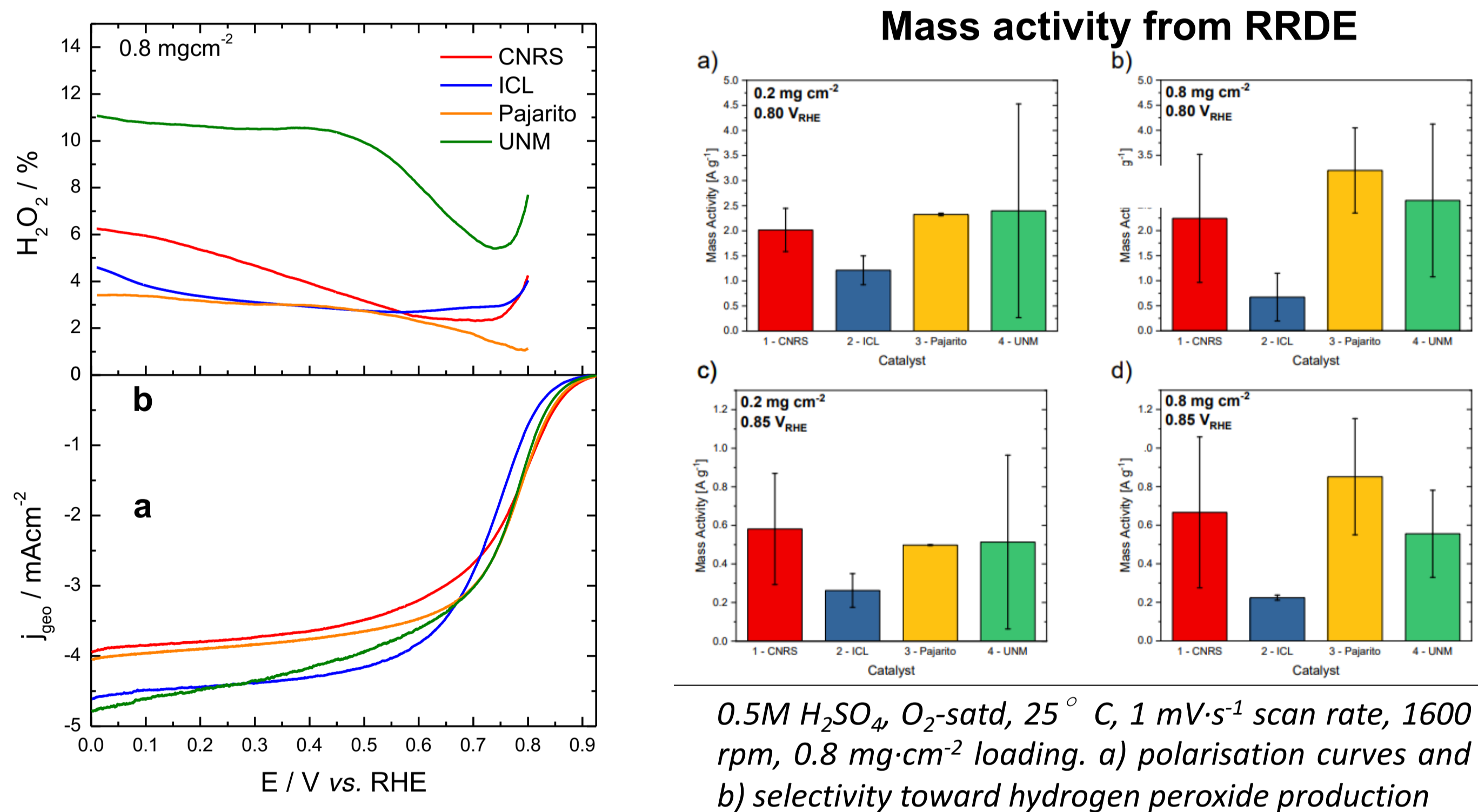✓ Increase **stability**

✓ Resolve **cathode mass transport limitation**

PROJECT STRUCTURE AND OBJECTIVES

New cathode catalysts, stabilisation approaches

Diagnostic methods to determine active site density and turnover frequency

0.42 W/cm² at 0.7 V, 1000 h with <30% loss at 1.5 A/cm², costs assessment

Redesign cathode layer construction adapted for non-PGM catalysts
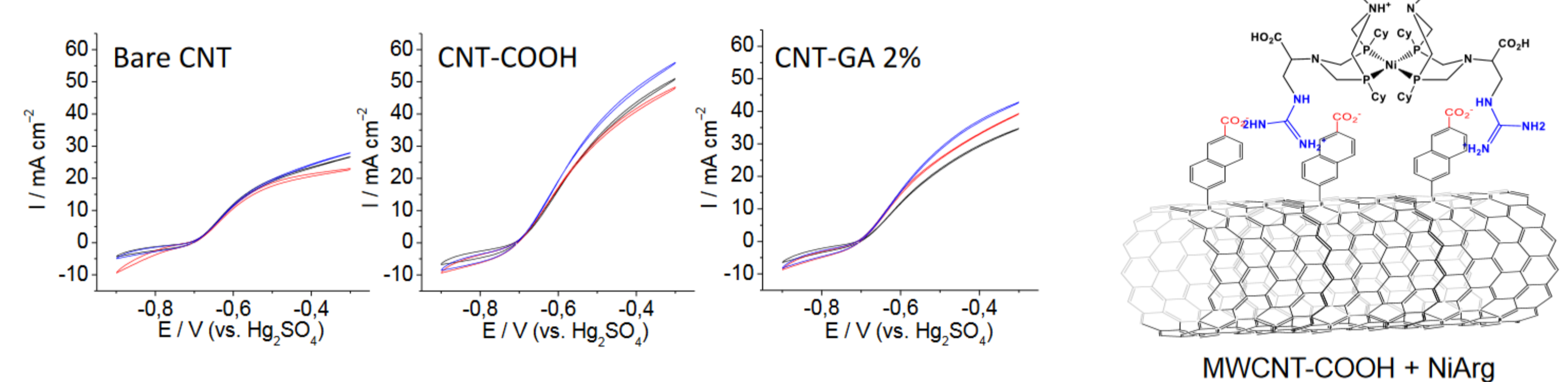
New CO and thiotolerant anode catalysts

NON-PGM CATALYST BENCHMARKING

Four State-of-the-Art Catalysts benchmarked:

✓ Rotating Ring Disk Electrode

✓ ^{57}Fe Mössbauer Spectroscopy, XPS, XRD, surface area

✓ CO chemisorption/nitrite stripping to determine site density and turnover frequency


Mass activity from RRDE

0.5M H_2SO_4, O_2-satd, 25 °C, 1 mV·s^{-1} scan rate, 1600 rpm, 0.8 mg·cm^{-2} loading. a) polarisation curves and b) selectivity toward hydrogen peroxide production

^{57}Fe Mössbauer spectroscopy

Relative % Fe Speciation

Room temperature ^{57}Fe Mössbauer spectra of the four benchmarked catalysts

JMFC 10 g scaled-up batch of CNRS hybrid 2 %Pt/Fe-N-C

NON-PGM ANODE

MWCNT-COOH + NiArg

Nickel phosphine based bioinspired molecular catalysts

✓ Supported on functionalised carbon nanotubes or graphenic acid

✓ High tolerance to CO

✓ Tolerance to H_2S under investigation

NON-PGM MEA BENCHMARKING

Air
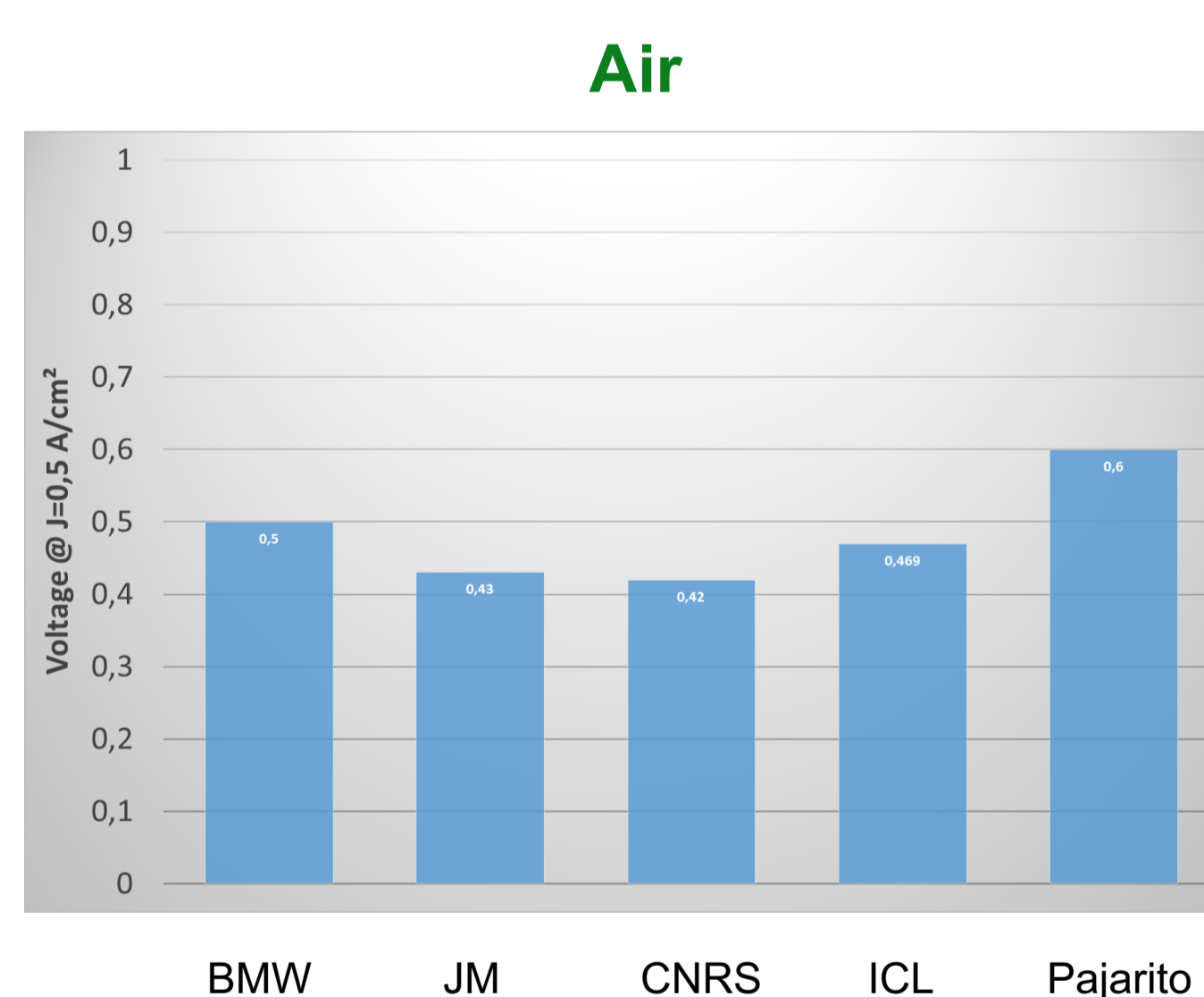
Pajarito Powder/EWII MEAs do not meet project targets

✓ Catalysts needed with significantly higher ORR activity and durability

✓ Catalyst layer thickness, <40 μm.

✓ Adjust I/C ratio to avoid blocking the mesoporous structure of the electrode, but without sacrificing the proton conductivity in the catalyst layer under dry operating conditions.

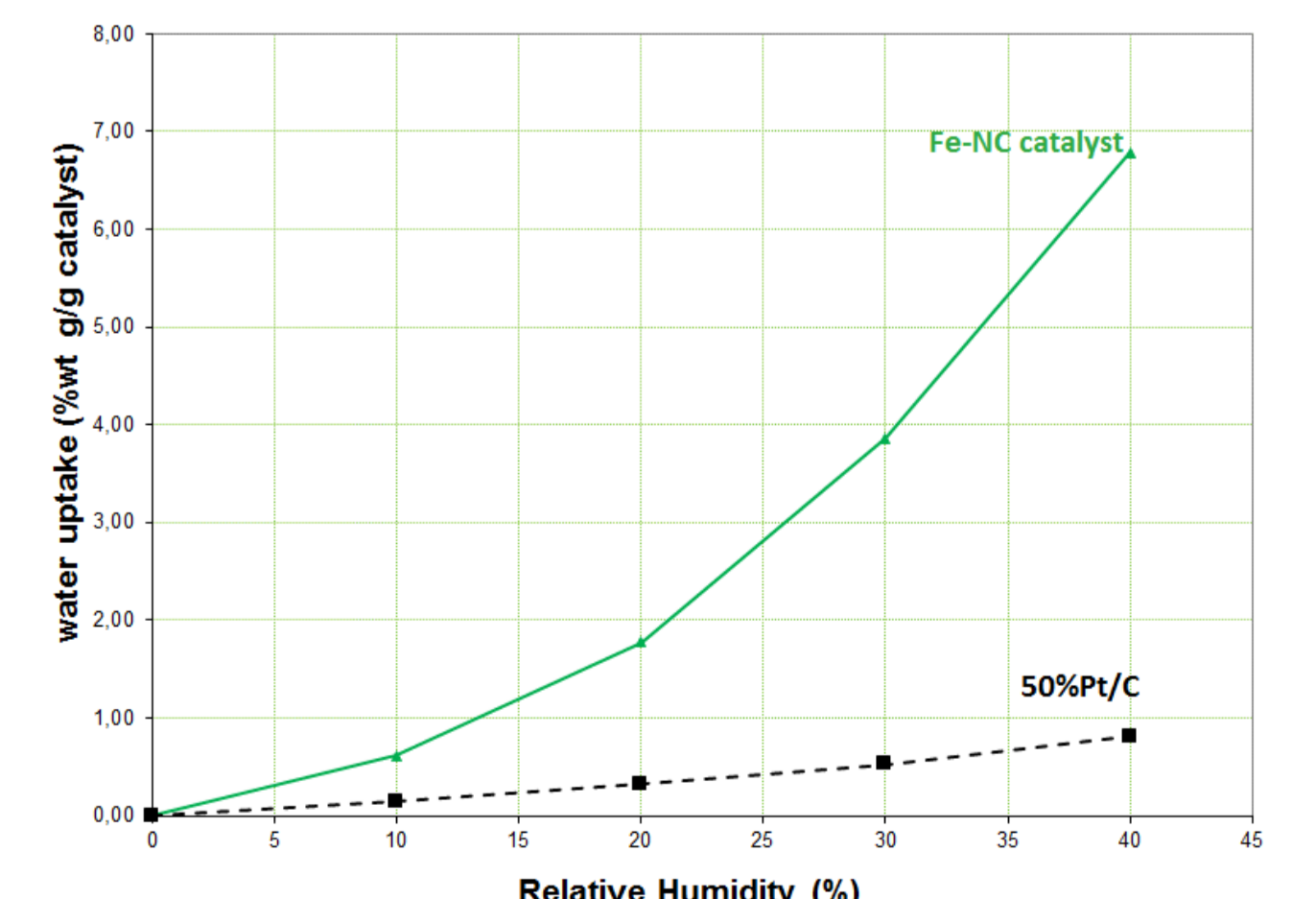## IDENTIFICATION OF TRANSPORT LIMITATIONS IN CATHODE LAYER

Mercury Intrusion Porosimetry
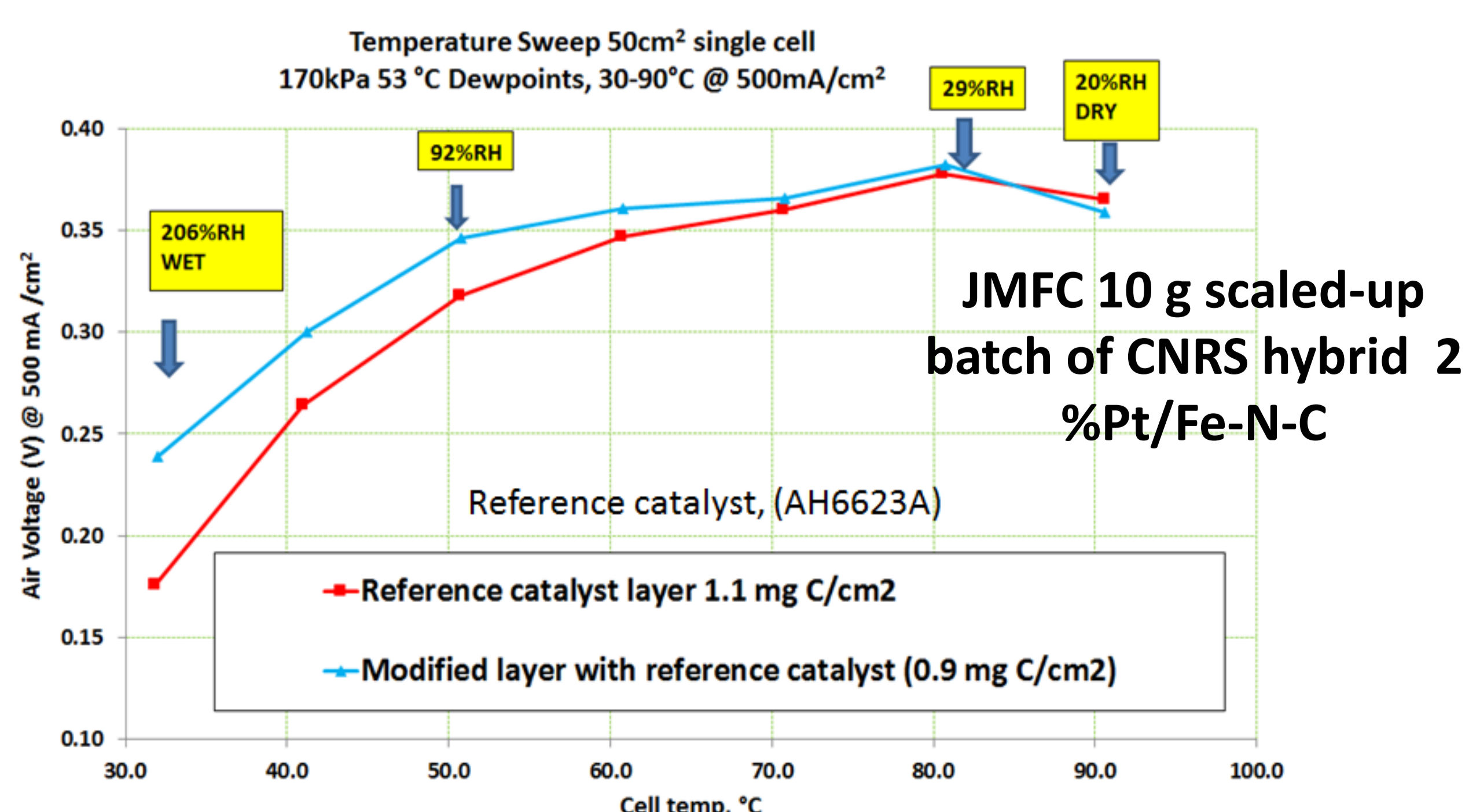

Effect of Humidity on Water Uptake
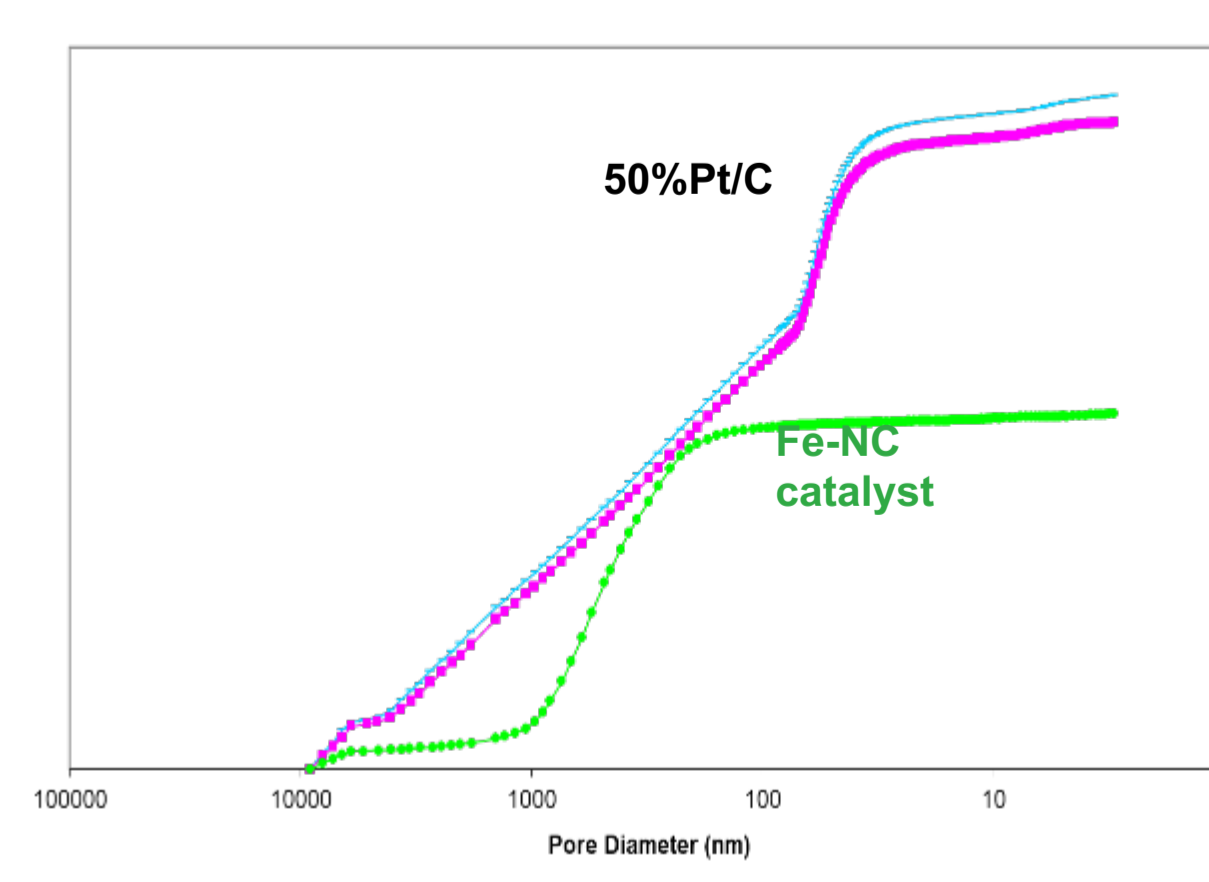
Mercury intrusion porosimetry comparing pore size of conventional Pt/C with MOF derived Fe-N-C catalyst

Low mesoporous volume in Fe-NC catalyst ➝ Poor mass transport properties